WATER & SEWAGE WORKS

FIRST AID FOR WATER MAINS!

Perchloron

REG. U. S. PAT. OFF.

Instantaneous sanitizer for emergency breaks!

The breakage of a water main at any point allows pollution to enter the water supply. Perchloron added to the water safeguards the supply by aiding in the elimination of such pollution.

Water works engineers have found Perchloron a dependable stand-by for just such emergencies because of its quick solubility, greater stability and high chlorine content.

In the water purification field, PERCHLORON is also used to sanitize small water systems, new mains, wells and swimming pools. Its properties include the oxidation of ferrous iron in water, the removal of hydrogen sulphide, the control of most types of algae and the destruction of chlorine susceptible bacteria.

PERCHLORON has been released by the military and is now available. Orders will be filled as promptly as we can meet demands.

PENNSYLVANIA SALT MANUFACTURING COMPANY

Chemicals

1000 WIDENER BUILDING, PHILADELPHIA 7, PA.

New York • Chicago • St. Louis • Pittsburgh • Cincinnati • Minneapolis • Wyandotte • Tacoma

WATER AND SEWAGE WORKS, April, 1946. Volume 93. Number 4. Published monthly by Gillette Publishing Co., 330 South Wells Street, Chicago, Ill. Per copy, 25c, except *this issue* 75 cents. Subscription rate, United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as Second Class Matter, March 12, 1946, at the Post Office at Chicago, Ill., under act of March 3, 1879.

$2000 IN CASH PRIZES

ENTER EITHER or BOTH—OPEN TO ALL

SPONSORED BY THE

PITTSBURGH EQUITABLE METER DIVISION
ROCKWELL *Manufacturing Company*

TO STIMULATE THINKING ABOUT THE COMMUNITY BENEFITS RESULTING FROM

100 PER CENT METERING

Complete the last line of this jingle

Water works systems should not be neglected,
All other utilities are meter protected.
When water is wasted, costs run high;
The mounting deficit makes taxpayers cry.
100% metering is the only fair way,
.....

This one is easy—anyone can enter and win. Study the principal advantages of 100% metering listed on this page. Then write a clever, informative last line for the jingle. As an example, the last line could read:

"To charge consumers, make water plants pay."

You can send in as many last lines as you wish.

PRIZE LIST

1st Prize—$500.00
2nd Prize—$250.00
3rd Prize—$100.00
4th Prize—$ 50.00
10 Consolation Prizes of $10.00 each

Write a paper not exceeding 2,000 words in length on the subject

"How A Community Is Benefited By Metering All Services"

Here is a topic all water works superintendents, municipal officials and engineers can write about. Contestants can either cite actual instances (with supporting data) to show where 100% metering has produced benefits to the communities concerned, or give their own arguments in favor of metering all services. Logic and clear thinking will count equally as well as past metering experience.

Contestants will, at the discretion of the Editor, be offered a $25.00 cash release fee for the use of their papers in the Pittsburgh-Empire Water Journal.

PRIZE LIST

1st Prize—$500.00
2nd Prize—$250.00
3rd Prize—$100.00
4th Prize—$ 50.00
10 Consolation Prizes of $10.00 each

TIPS ON ADVANTAGES OF 100% METERING

Metered consumers only pay for the water that is used —not for someone else's waste.

Metering discourages water waste—often cuts per capita distribution in half—conserves power, lowers treatment costs.

100% metering, by eliminating extravagant use of water, frequently curtails the need for costly added sources of supply.

By metering all services the burden caused by excessive wasted water on overloaded sewage disposal systems can be relieved.

Meters produce added revenue, usually enough to cover initial investment, maintenance costs and depreciation.

The meter system provides the only fair and equitable basis for apportioning water charges to all consumers.

Use the COUPON below: Fill in coupon with name and address. Clip, pin or staple to entry sheet or sheets. Upon receipt a code number will be assigned to each contestant and this number alone will appear when subject matter is being considered by the board of judges. No entries accepted without coupon.

CONTEST RULES and REGULATIONS

Everyone is eligible to participate except employees and members of their families of any DIVISION or SUBSIDIARY or ROCKWELL MANUFACTURING COMPANY and their Agents.

All entries must be accompanied by coupon clipped from any contest announcement. Only one coupon is required to identify a contestant who submits a number of entries at the same time.

Write on one side of paper only. *DO NOT* put name or address on any entry. An executed coupon will serve as contestant's identification.

Contests close August 31, 1946. Entries must be postmarked on or before that date.

Winners names in both contests will be posted in Pittsburgh-Empire Meter exhibit booths at the fall water works conventions. Checks will be mailed to winning contestants immediately upon completion of judging.

All entries will be impartially judged by a panel of informed water works authorities. Names will be announced later.

The decisions by the judges will be final and no entries will be returned.

In case of ties, duplicate prizes will be awarded.

TEAR OUT THIS COUPON NOW!

PITTSBURGH EQUITABLE METER DIVISION
ROCKWELL MANUFACTURING CO.
400 N. Lexington Ave., Pittsburgh 8, Pa.

Attached find my entry or entries for
CONTEST NO. 1 ☐ CONTEST NO. 2 ☐
Check in boxes provided. Where entries are submitted in both contests, check both boxes.

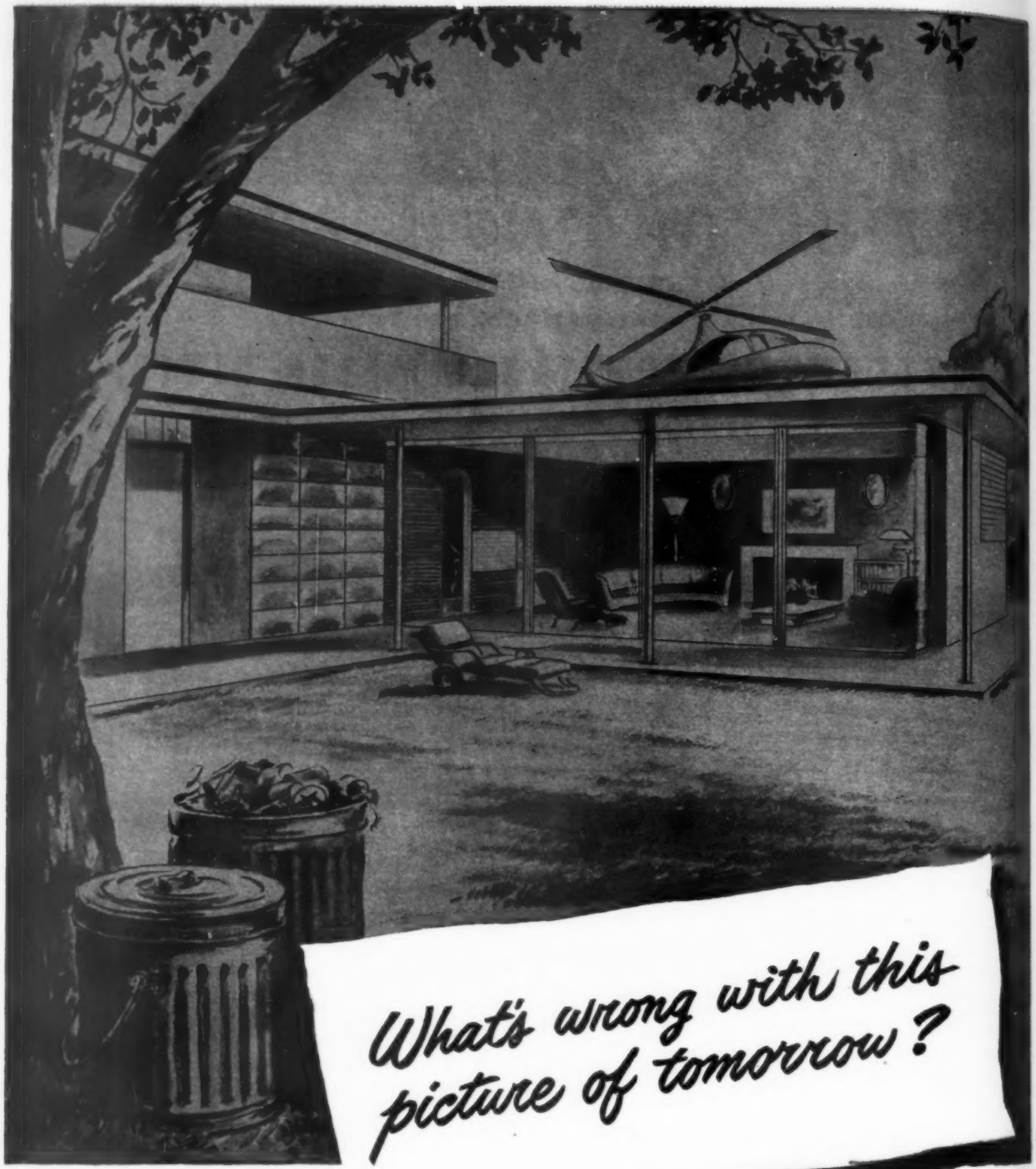
Your Name..... Title.....

Business Connection.....

Street.....

Town..... State.....

CONTESTS CLOSE AUGUST 31, 1946



TRUE, no one can foresee exactly what the dwelling places of tomorrow will be like. But—in one detail—our artist's conception is wrong. For, standing in stark ugliness amid all the glorious improvements shown here, is a garbage can. And the garbage can, we are firmly convinced, will become a thing of the past.

As an expert in the field of sanitation, you are especially aware of the threat to health offered by exposed organic waste materials. In fact, you have always endeavored to protect your community from the diseases which the two related wastes—sewage and garbage—may foster. And you have won a notable victory over one of these wastes. For today typhoid is almost unknown.

Thus you will be vitally interested in seeing garbage cans eliminated as a menace to public health.

How can they be eliminated?

By means of the General Electric Disposall! Installed in home kitchens, this appliance removes food wastes *immediately* by shredding them into fine particles and flushing them into the sewer. *And it does not interfere with present sewer systems or sewage treatment practices.*

Because the Disposall can double the usefulness of your sewer system and sewage treatment plant and help you still further safeguard the health of your community, we believe every sanitary engineer will want to know more about this new trend in food-waste removal.

QUESTIONS AND ANSWERS ABOUT IMPROVED FOOD-WASTE REMOVAL METHODS

1. Has the Disposall method been tested?

Yes—during the past ten years, in numerous research and testing laboratories—and in over 300 communities. The information thus accumulated proves definitely that the Disposall method of removing food waste is 100% practical.

2. Will Disposall-treated wastes obstruct sewer systems?

No. Food wastes are similar to human wastes and other sewage solids. But when food wastes pass through the Disposall, they are processed into minute particles which are more uniform and water-buoyant than the sewage solids now flowing through your lines. The processed solids will not shoal, settle, adhere to pipe lines, or cause sewer stoppages.

3. Need you worry about your plant's capacity?

Even if *every* home were equipped with a Disposall, the increase of volume of flow would be only about 1%. Naturally, the addition of food wastes to the sewer system will increase the solids and organic loading on treatment plants. But it will be many years before there are enough Disposalls in use to increase present loadings appreciably.

4. Should steps be taken now?

Just as indoor plumbing replaced the outhouse, the G-E Disposall should replace the garbage can. For it removes all food waste as it should be removed—*immediately!*

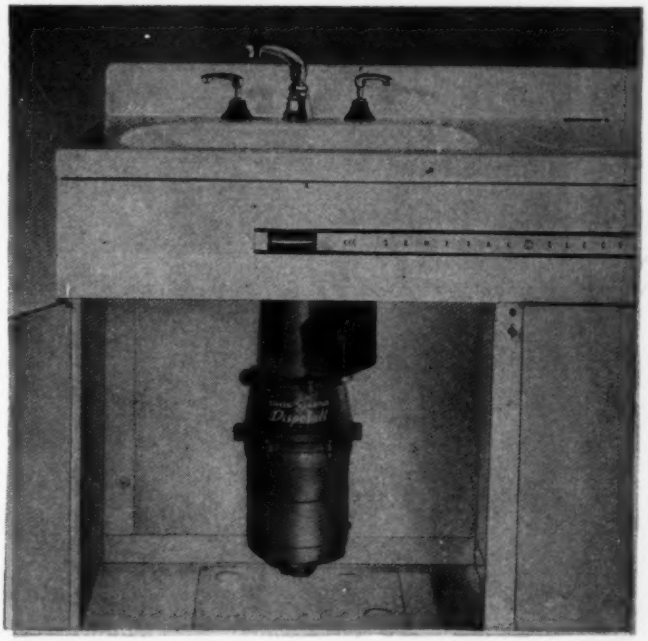
Like the outhouse, the garbage can threatens community health. It is odorous, putrefactive, germ-breeding. It attracts flies which spread those deadly germs. *The sooner it is eliminated, the better!*

5. Is a sewage treatment plant necessary?

Whether Disposalls are used in your community or not, we believe that every modern American city should have a sewage-treatment plant. And we hope that public-spirited men will continue to crusade for such plants where they are needed, and use the advantages of the Disposall to support their cause!

6. Have we more detailed information?

Yes! Further interesting facts about the Disposall—the result of intensive research—are available to you upon request. We shall be glad, too, to answer any specific questions you may wish to ask. Please write to Department SWJ545, General Electric, Bridgeport 2, Conn.



The G-E Disposall as it appears installed in the G-E Electric Sink. Food wastes are scraped into drain opening, safety cover placed in position, and *cold* water turned on. The turning on of the cold water starts the Disposall. Food waste is grated and flushed away, automatically.

Disposall

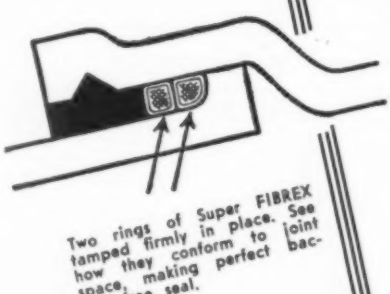
REG. U. S. PAT. OFF.

CONVERTS FOOD WASTE TO SEWAGE—ELIMINATES "GARBAGE"

GENERAL ELECTRIC

FIBREX is the very last word in packing for cast iron bell and spigot joints. A clean, sleek rubber jacket has been added to bacteria-free FIBREX to make it the most sanitary packing ever produced.

Super FIBREX comes ready to use—cut to exact pipe size. It packs into the joint perfectly, comforming to the pipe contours, making a tight bond—rubber to metal. Used with HYDRO-TITE it makes the finest joint ever developed for bell and spigot water mains.



Two rings of Super FIBREX tamped firmly in place. See how they conform to joint space, making perfect bacteria-free seal.

Now

HYDRO-TITE

Joints Will Be Better

Than Ever Before

Hundreds of water works men can attest to the fact that HYDRO-TITE has joined thousands of miles of cast iron pipe with complete satisfaction. Now, by using super FIBREX an even better joint results. Super FIBREX, when properly tamped in, takes the shape of the pipe end and makes a permanent rubber-clad gasket. Due to the construction of Super FIBREX there are no open or weak spots. It makes a complete seal—rubber to metal.
Use Super FIBREX—with time-tested HYDRO-TITE for permanently tight bell and spigot joints.

A PIPE LINE
IS NO BETTER
THAN ITS JOINTS

HYDRO-TITE

A DEPENDABLE SELF-CAULKING JOINTING COMPOUND

Plus

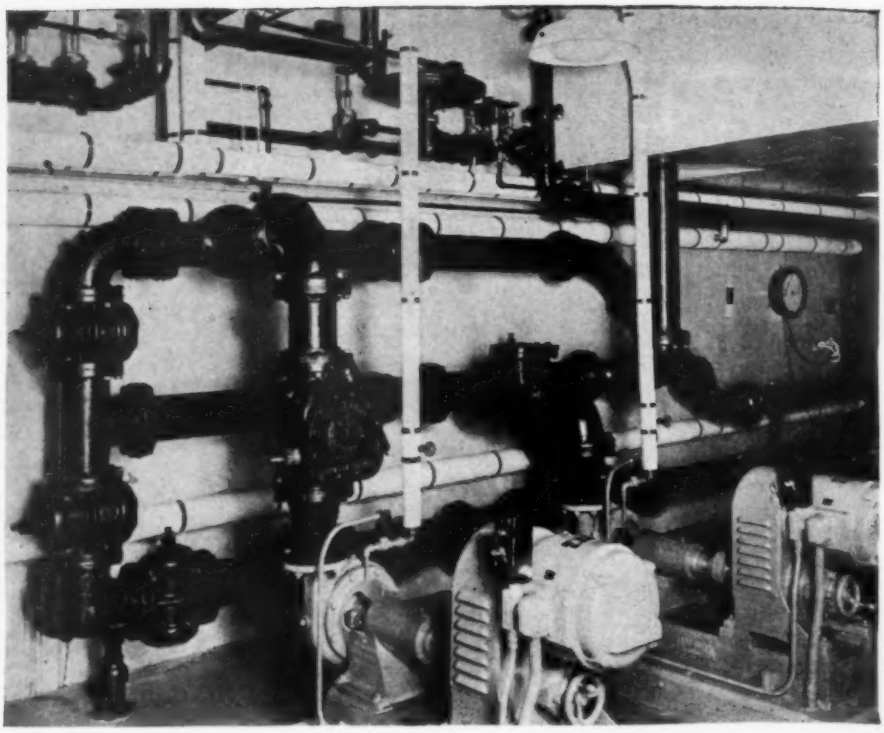
Super FIBREX

A BACTERIA-FREE RUBBER COVERED, USED LIKE BRAIDED JUTE

HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office: 50 Church Street, New York, N. Y.

General Office and Works: West Medford Station, Boston, Mass.



Again it's A.C.F. Lubricated Plug Valves in Sludge Pump Room at Peru, Illinois showing A.C.F. 6-inch Plug Valves on Sludge Lines.

Yes, Mr. Cole... *Plug valves are* *INSURANCE against stoppages*

We agree with Mr. Harvey M. Cole, Jr., Sanitary Engineer, San Diego, California —that plug valves have proven their superiority in sludge lines.

In the December 1945 issue of Sewage Works Engineering the Round Table Discussion deals with "Stoppage of Sludge Lines at Treatment Plants". Mr. Harvey M. Cole, Jr., one of the many prominent engineers interviewed stated:

"We use eight-inch sludge lines throughout the plant. All sludge lines are of cast iron. There are a few four-inch gate valves next to the sludge pumps (discharge side), but all large eight-inch valves are plug valves, some straight-through, some three-way and some two-way. Our experience has proven the worth of plug valves on sludge lines. Rags, stringy material and sticks that somehow get through to the valves, causing stoppages, are more readily cleared by shearing the material in the valve by turning the handle ninety-degrees. Gate valves are not strong enough to stand this shearing action."

We can supply plug valves with the same face-to-face dimensions as existing gate valves. There is no need to disrupt present installations in modernizing your sewage disposal plant. Distributors in principal cities carry adequate stocks. For complete specifications send for catalogue 3-W.

a.C.f. **AMERICAN CAR AND FOUNDRY COMPANY**
Valve Department
30 CHURCH STREET · NEW YORK 8, N. Y.

The Nameplate of DEPENDABILITY

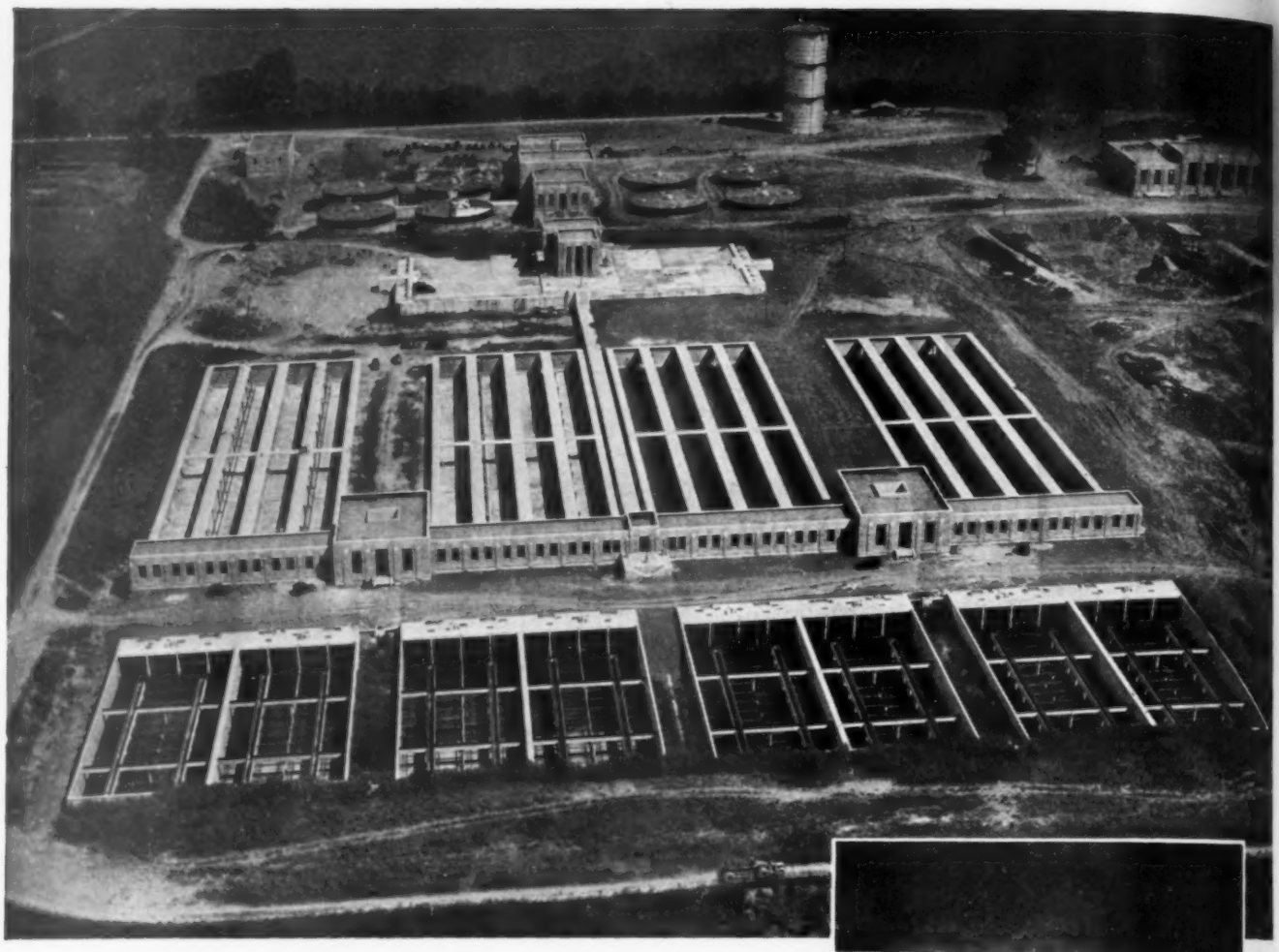
The plus values that come with Roberts Filter equipment are intangibles of long experience, engineering skill and the ability to work with others.

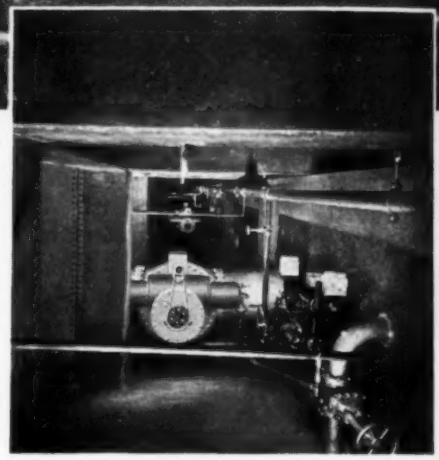
Evidence of the fine reputation Roberts Filter Mfg. Company enjoys, is to be found in the fact that hundreds of major projects and thousands of smaller installations for water treatment in operation today, bear the Roberts nameplate of dependability.

We invite the opportunity to cooperate with individuals and organizations interested in the correction of water, either for municipal or industrial requirements. Your request will bring full information on the application of our products and services.

ROBERTS FILTER MANUFACTURING CO.

607 COLUMBIA AVENUE • DARBY, PENNSYLVANIA





ROTOVALVES

by

S. MORGAN SMITH COMPANY

For CHECK SERVICE with RAW SEWAGE PUMPS

In the Sewage Treatment Plant of the CITY of COLUMBUS, Ohio

SAFEGUARDING the two 55 m.g.d., and the two 27½ m.g.d. motor driven Raw Sewage Pumps, the four Roto Check Valves perform an essential service, in this modern and important Plant.

One of the very interesting characteristics of this installation is that they are located downstream from the throat of the Venturi meters, which are set between the pumps and the check valves. These four valves are included in a total of 48 S. Morgan Smith Company Rotovalves used in this plant for miscellaneous services on air, sludge and sewage lines.

Write us for more complete information, when you are planning Sewage Plants.

S. Morgan SMITH Company

YORK • PA.

CUBICLE CONTROL CENTERS *are available for all* SEWAGE DISPOSAL *and* WATER TREATMENT PLANT ELECTRICAL CONTROL INSTALLATIONS

"3C" Cubicle Control Centers comprise three basic panel forms —Incoming Line, Motor Control, and Gauge Cubicles. All are matching in height, depth, general construction and appearance. Cubicle equipment for any given installation may be determined easily as follows: 1. Tabulate number, horsepower and voltage of motors involved and starters required, also whether full or reduced voltage starting is needed. (See Table 1). 2. Select Motor Control cubicle type. (See Table 2). 3. Select Incoming Line cubicle type based on total horsepower. (Table 3). 4. Physical arrangement can be made to suit installation. For overall dimensions and building design ask for "3C" Bulletin 9900.

TABLE No. 1. HORSE-POWER RATING VS. STARTER SIZES

Max. H. P., 3 Phase Induction Motors		NEMA	Contactor
208-220 Volts	440-550 Volts	Starter Size	Amp. Rating
2	2	No. 0	15
5	7½	No. 1	25
15	25	No. 2	50
30	50	No. 3	100
50	100	No. 4	150

TABLE No. 2. MOTOR CONTROL CUBICLES

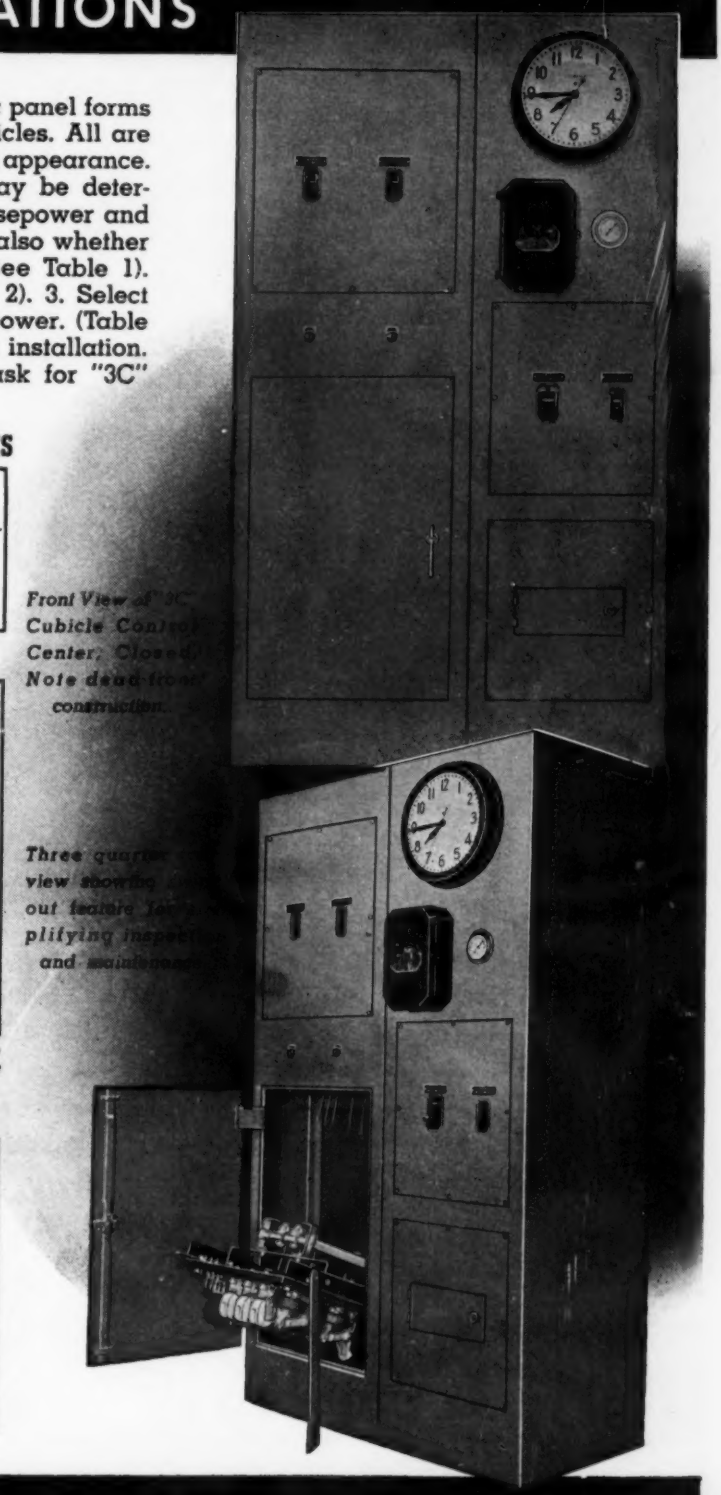
*Max. No. and Sizes of Motor Starters per Cubicle			Cubicle Type
Full Voltage (Bulletin 6013 Type)		Reduced Voltage (Bulletin 6080 Type)	
4–Size 0 or 1		.....	M4-X1
6–Size 0 or 1		.....	M6-X1
4–Size 2		.....	M4-X2
6–Size 2		.....	M6-X2
1–Size 2	and	1–Size 2	M2 X2-R2
3–Size 2	and	1–Size 2	M4-X3-R1
.....		2–Size 2	M2-R2
2–Size 3		.....	M2-X3
.....		1–Size 3	M1-R3
1–Size 1	and	1–Size 3	M2-R3-X1
1–Size 3 and 1–Size 4		.....	M2-X3-X4
2–Size 4		.....	M2-X4
.....		1–Size 4	M1-R4

*The number and sizes of starters shown for each cubicle type are the maximum. In any case, smaller sizes may be substituted; i.e., Cubicle type M4-X2 will accommodate 2 size 2 and 2 size 1 starters, etc.

TABLE No. 3. INCOMING LINE CUBICLES

Max. H.P. Capacity		3 Pole Circuit Breaker Frame Size	Cubicle Type
220 Volts	440 Volts		
15	35	50 Amperes	IL-50
35	75	100 Amperes	IL-100
85	170	225 Amperes	IL-225
250	500	600 Amperes	IL-600

Cubicle Type	Number of Lighting Panel Circuits	Panel Space Available for Power Co. Metering Equipment
IL-50	8–Single Wire	32" H. x 18" W.
IL-100	8–Single Wire	32" H. x 18" W.
IL-225	8–Single Wire	28" H. x 18" W.
IL-600	8–Single Wire	22" H. x 18" W.



Front View of "3C" Cubicle Control Center, Closed. Note dead front construction.

Three quarter view showing out feature for simplifying inspection and maintenance.

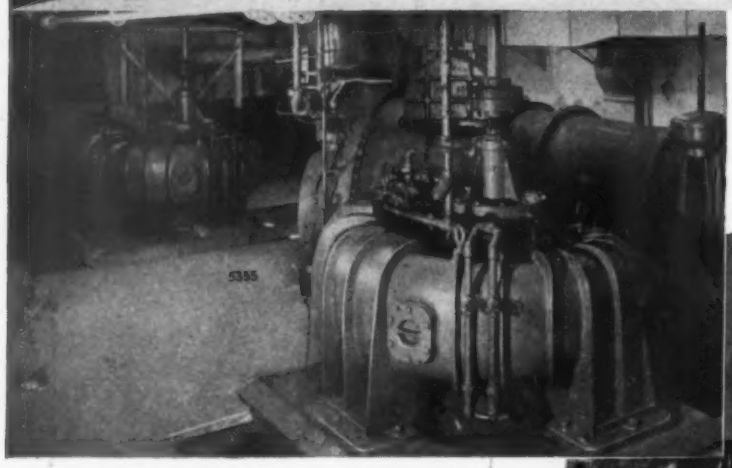
THE CLARK CONTROLLER CO.

1146 EAST 152nd ST., CLEVELAND 10, OHIO • EVERYTHING UNDER CONTROL

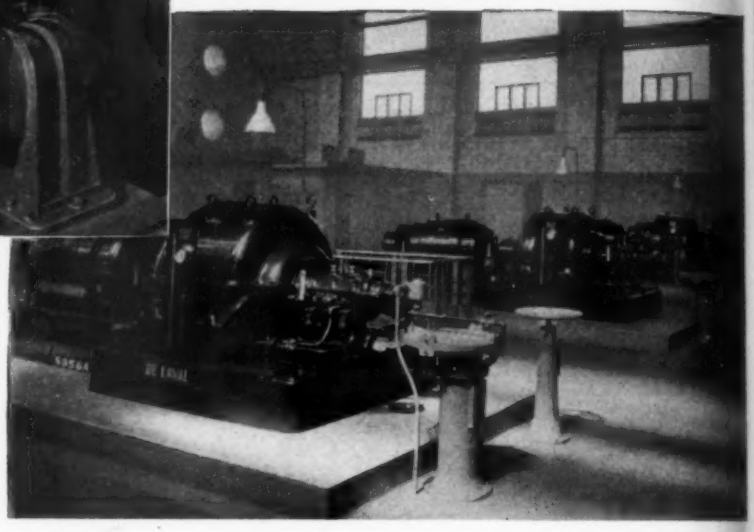
SEWAGE GASES GENERATE THE POWER

for DE LAVAL PUMPS and COMPRESSORS

in BOWERY BAY SEWAGE DISPOSAL PLANT



Two of a battery of four De Laval mixed-flow pumps at Bowery Bay. Each of the 36" pumps delivers 29,480 g.p.m. against 40 ft. head.



Four De Laval compressors at Bowery Bay, each of which delivers 10,000 c.f.m. against 7¾ psi. These compressors are directly connected to high-speed 3500 r.p.m. slipring motors.

All pumping in the modern 60 m.g.d. Bowery Bay Sewage Disposal Plant, serving the City of New York, is handled by De Laval mixed-flow centrifugal pumps; and all air required by the activation chambers is delivered by de La Val compressors.

Approximately half of the power needed to drive these units is furnished by generators driven by gas engines receiving fuel in the form of gas from the digestion chambers.

Bowery Bay is one of many sewage disposal plants served by De Laval pumps and compressors.

TURBINES • HELICAL GEARS • WORM GEAR SPEED REDUCERS CENTRIFUGAL PUMPS • CENTRIFUGAL BLOWERS and COMPRESSORS • IMO OIL PUMPS

DE LAVAL

STEAM TURBINE COMPANY · TRENTON 2, NEW JERSEY

SALES OFFICES: ATLANTA • BOSTON • CHARLOTTE • CHICAGO • CLEVELAND • DENVER DETROIT • DULUTH • EDMONTON • GREAT FALLS • HAVANA • HELENA • HOUSTON KANSAS CITY • LOS ANGELES • MONTREAL NEW ORLEANS • NEW YORK • PHILADELPHIA PITTSBURGH • ROCHESTER • ST. PAUL • SALT LAKE CITY • SAN FRANCISCO • SEATTLE TORONTO • TULSA • VANCOUVER • WASHINGTON, D. C. • WINNIPEG

You are cordially invited to visit the De Laval Booths, Nos. 79 and 80, at the Water Works Convention, St. Louis, Missouri.

ZECO GREENSAND ZEOLITE

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

★

ZEOLITE CHEMICAL CO.

Sales Office
140 Cedar St., New York, N. Y.

Factory
Medford, N. J.

Pioneer Producer of GREENSAND ZEOLITE MINERAL

Pin a Medal on the Engineer who said,

"CLEAN WATERMAINS FIRST . . . . BEFORE ADDING NEW & LARGER WATERMAINS"

Flexible Pressure Tool utilizes pressure of fluid flowing through pipe.

OFFICIALS of one city would like to pin a medal on the engineer who made the above statement, because their water department increased pumping capacity 365,000,000 gallons per year by having Flexible clean their mains. In actual profit over a period of five years, they saved $3,650 a year plus the value of the additional water pumped, which was estimated to be approximately $2,663. This pipe cleaning job, costing $2,000.00, actually paid 200% profit the *first year* and continued to pay each year for five years.

Tests made this year (the fifth test) show little change. This city's name will be furnished on request.

Clean your pipe lines *first*. Save costly cuts in the street — call, write or wire Flexible for an estimate on your pipe cleaning problems.

Centrifugal force throws chain head cutters in contact with pipe to remove tuberculation.

Flexible crews are equipped to handle any pipe cleaning job. Flexible power unit is shown.

615 Pickwick Bldg.
Kansas City 6, Mo.
1624 Harmon Place
Minneapolis 3, Minn.
P.O. Box 165
Atlanta
P.O. Box 694
Gulfport, Miss.
41 Greenway St.
Hamden, Conn.

1208 W. Chase Ave.
Chicago 26
147 Hillside Ter.
Irvington, N. J.
P.O. Box 694
Pittsburgh
401 Broadway
New York 13
29 Cerdan Ave.
Roslindale 31, Mass.

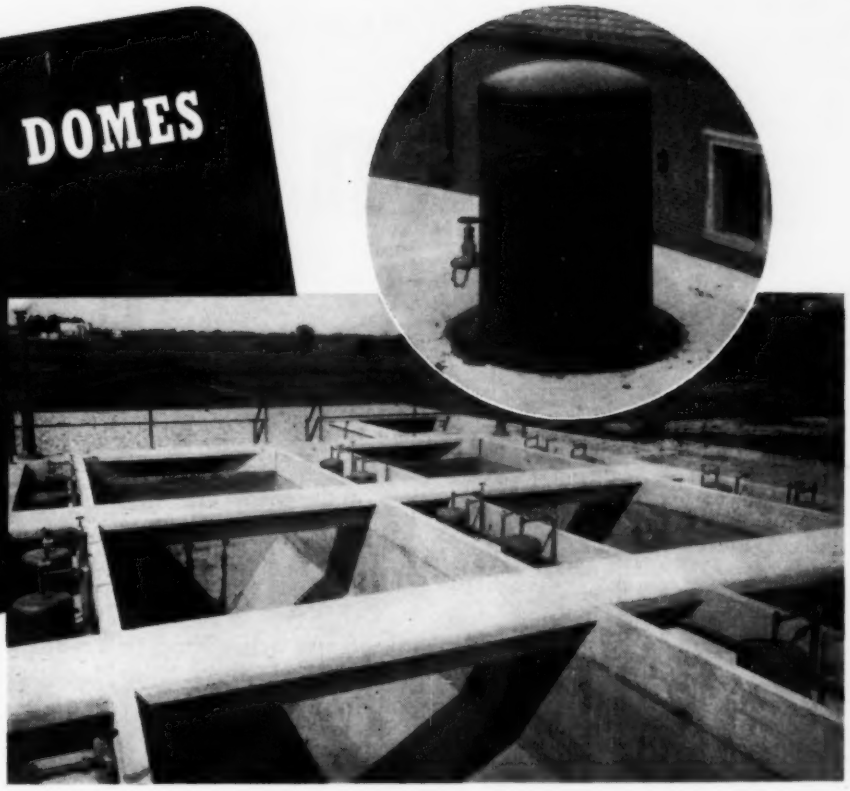
Fleets of trucks (illustrated) are strategically located throughout United States.

FLEXIBLE WILL CLEAN ANY PIPE FROM 2 TO 72 INCHES

Flexible UNDERGROUND PIPE CLEANING CO.

9059 VENICE BOULEVARD • LOS ANGELES • CALIF.

COLLECTION DOMES suffering from GAS ATTACKS?



MAINTENANCE TIPS FOR CORROSIVE SEWAGE SERVICES

try BYERS WROUGHT IRON

If you are using gas from digesting sludge for heating or for power, you know it can mean plenty of trouble for collection equipment.

In addition to methane, the gas contains carbon dioxide and hydrogen sulfide. Both carbon and sulphur compounds become aggressive acids in the presence of moisture. Since the gas is always moist, collection domes and hoods are exposed to severe attack.

Fortunately, this is an application where wrought iron has proved its superior durability. Designers have used it in a number of the most modern plants in the country. The collection domes shown in the illustration above, and used in two Indiana installations, were fabricated from Byers Wrought Iron 8-gage sheets by welding. In a Michigan installation, hoods for use in 2-story tanks were made from 11-gage wrought iron sheets.

The reason for wrought iron's superior corrosion resistance in this service is found in its unusual composition and structure. Tiny fibers of glass-like silicate slag—200,000 or more to the square inch of section—are threaded through the main body of high-purity iron. These fibers act like baffles, to halt and diffuse corrosive attack, and so discourage pitting and penetration. When galvanizing is used, the microscopically rougher surface of wrought iron retains a heavier coating.

If the material you are now using for collection domes requires frequent replacement, you will find it profitable to investigate the service and economy record of wrought iron. Our bulletin, "Wrought Iron for Sewage Treatment and Disposal Installations" will give you some helpful, factual information. We will be happy to send you a complimentary copy on request.

A. M. Byers Co., Pittsburgh, Pa. Established 1864. Boston, New York, Philadelphia, Washington, Chicago, St. Louis, Houston, Seattle, San Francisco, Atlanta.

CORROSION COSTS YOU MORE THAN WROUGHT IRON

Can you think

There's a fortune in it if you can.

But remember, we mean pipe material that *will* serve for a century. Everybody knows that cast iron pipe will because it *has* served for more than a century in American cities, and for more than two centuries in Europe.

Can you think of any other kind that will? Under the ground and under pressure? At practicable cost? No one else has been able to.

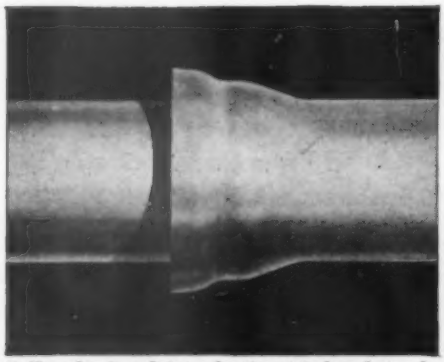
But, you may say, in this Atomic Age why should I buy pipe that lasts so long? Because the same qualities that enable cast iron pipe to serve for centuries also mean economy "in our time." Lower annual maintenance cost from the start. Lowest cost per service year in the end.

A survey among 195 water works superintendents proves that the maintenance cost of cast iron pipe for distribution mains is lowest by far.

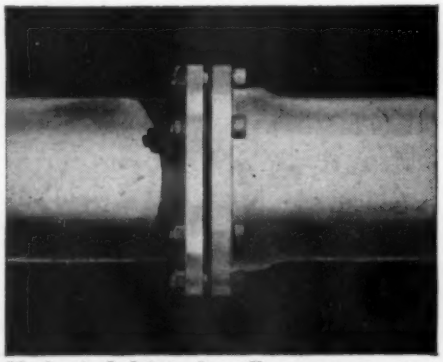
Engineers, in evaluating bids, continue to give cast iron pipe the highest rating for useful life — 100 years or more.

A U. S. Government Report On Obsolescence gives cast iron pipe the lowest rate of depreciation of all engineering materials.

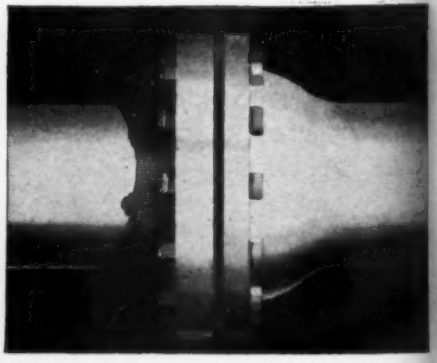
Yes, you can lay cast iron pipe with confidence, underground or under water. Because of its all-purpose adaptability, cast iron pipe is available with joints for every service as shown below. Cast Iron Pipe Research Association, T. F. Wolfe, Research Engineer, Peoples Gas Bldg., Chicago 3.



Bell-and-spigot Joint—the time-tried and standard for water, gas and sewerage service.



Mechanical Joint—for all pressures—now standardized with interchangeable parts.



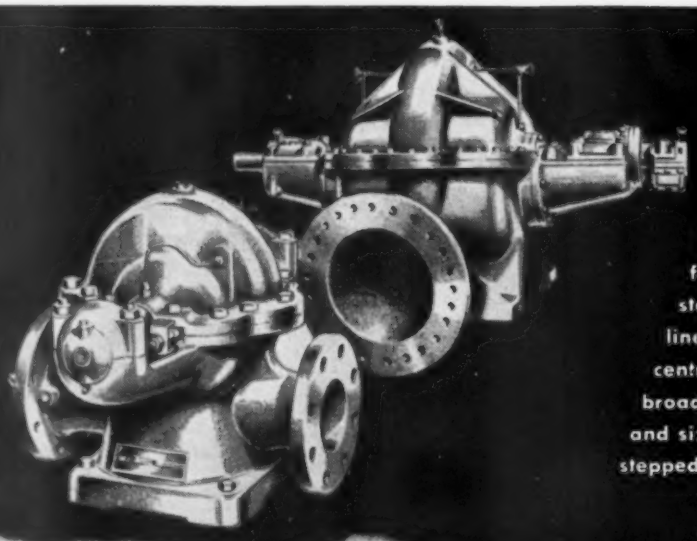
Flexible Joint—for river crossings and other sub-aqueous installations.

CAST IRON PIPE

of any other pressure pipe material, practicable for underground mains, that will serve for a century?

Flanged Joint—for water, steam, oil or gas lines, generally used above ground.

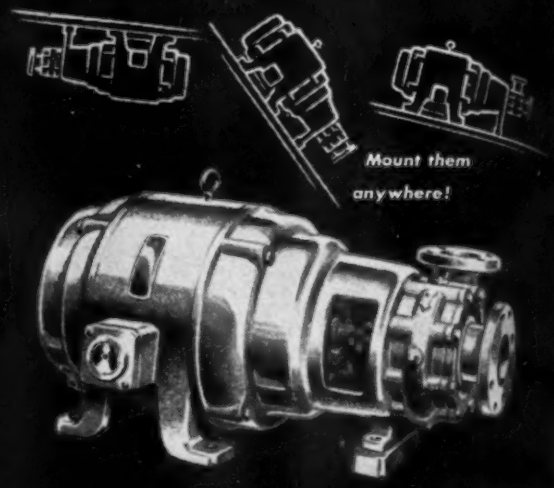
Serves for Centuries



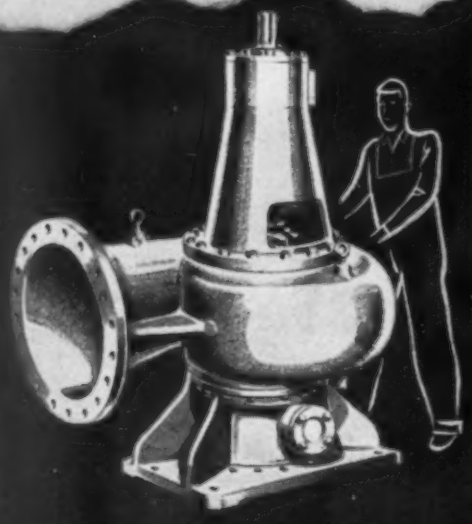
The older they are the farther they fall in attempting to meet standards that are being set by the line of Fairbanks-Morse split-case centrifugal pumps. Here's a line that's broad enough to include the type and size which most closely meets your stepped-up needs.

Time to Forget . . . and Remember!

Now is the time to forget your old pumps whose efficiency is that of a bygone era and whose daily services are costing you money! Remember—pumps are commonly designed and built to answer specific conditions of head and capacity: When these conditions change, the increase in pumping costs may be appreciable.



Replace tired-out, hard-to-get-at pumps with Fairbanks-Morse Builtogether pumps—packaged units, with pump and motor on a single shaft. Used industry-wide, they move up to 1200 gallons per minute at heads up to 260 feet.



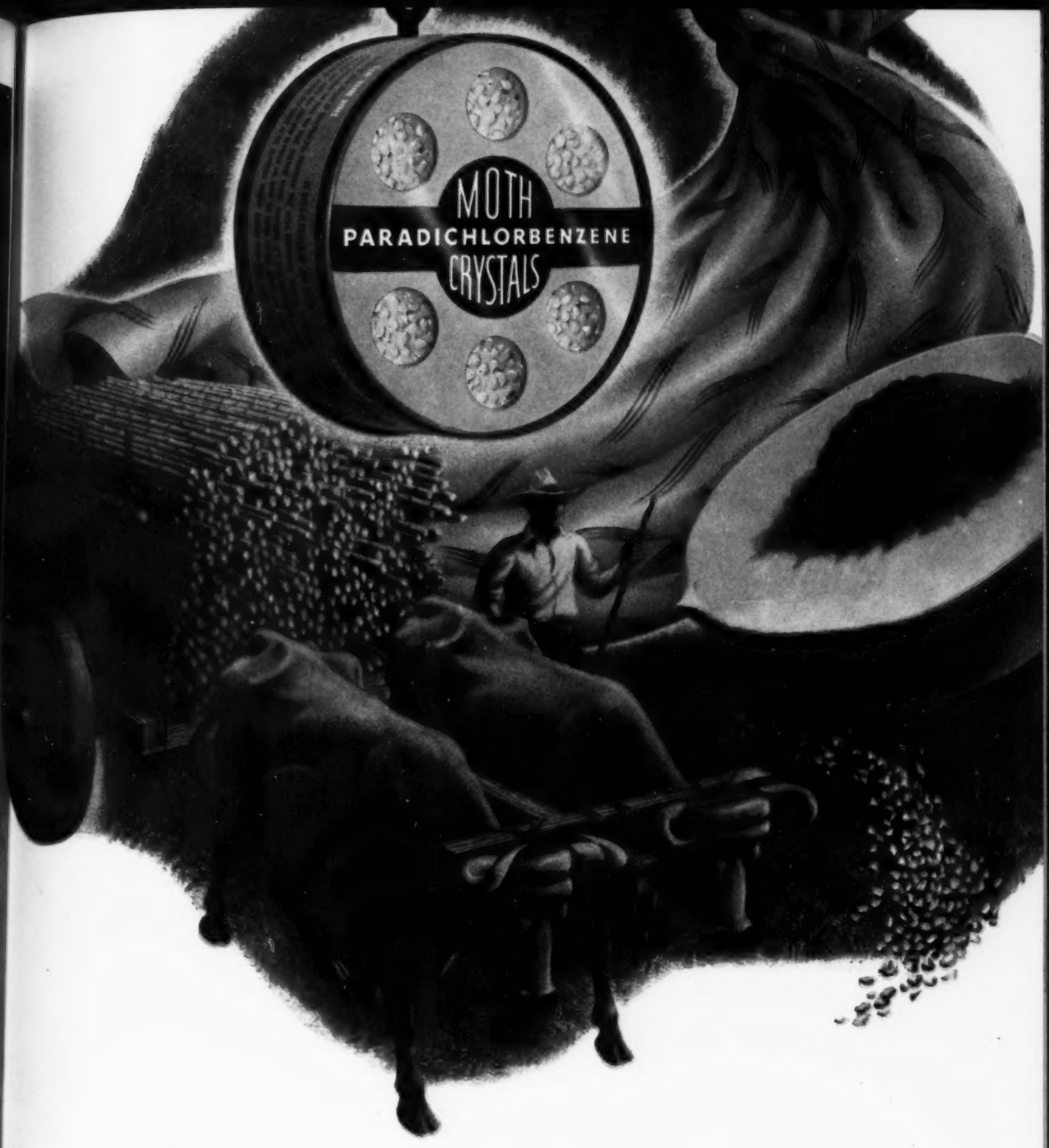
Name your pumping job— there's a modern Fairbanks-Morse "high-efficiency" pump ready to handle it. For instance, the line of vertical Angle-Flow pumps for moving lots of water—up to 80,000 g.p.m.—at a cost that, even compared with modern standards, is extremely low.

Three famous names— Fairbanks-Morse, Pomona and Westco are gilt-edged evidence that when you see your Fairbanks-Morse dealer or call at your Fairbanks-Morse branch office, you're taking the right step toward lowest liquid-moving costs.

FAIRBANKS-MORSE

A name worth remembering

DIESEL LOCOMOTIVES · DIESEL ENGINES · MAGNETOS · GENERATORS · MOTORS · PUMPS
SCALES · STOKERS · RAILROAD MOTOR CARS and STANDPIPES · FARM EQUIPMENT



Typical of the many "staple" materials in which quality should not be "taken for granted" is Paradichlorobenzene. The basic efficiency of this material as an insecticide for the control of the peachtree borer or sugar cane grub . . . as a moth-killing fumigant and deodorant . . . or as a dye intermediate, depends in large measure on the clean, pure quality of "Para" crystals. Long experience has given Niagara special knowledge in the processing and handling of Paradichlorobenzene. In addition, Niagara is equipped to cooperate expertly with customers regarding its use in a wide range of applications.

An Essential Part of America's Great Chemical Enterprise

Niagara Alkali Company

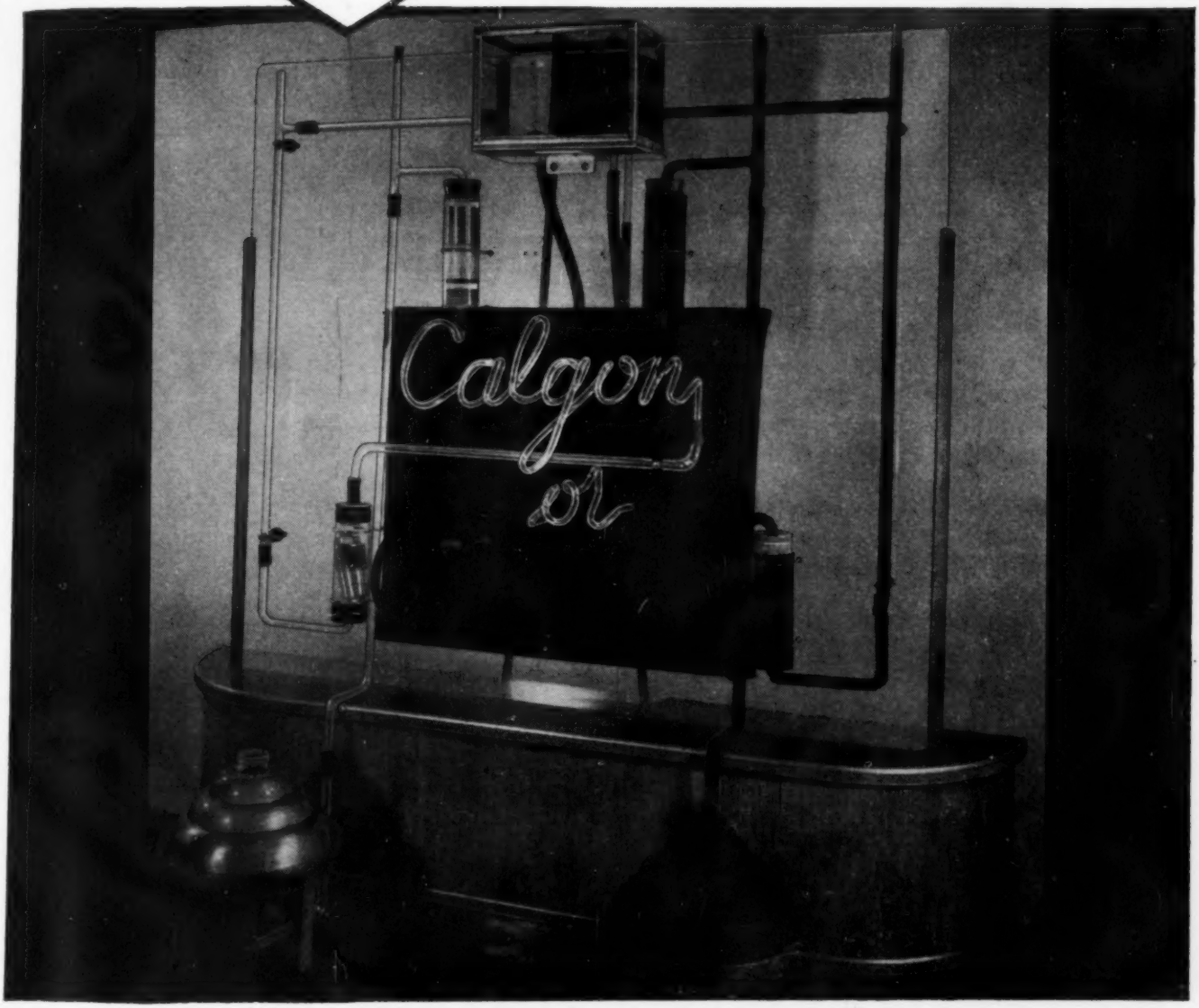
CAUSTIC POTASH • CAUSTIC SODA • PARADICHLOROBENZENE • CARBONATE OF POTASH • LIQUID CHLORINE • NIATHAL

60 EAST 42nd STREET • NEW YORK 17, N. Y.

American Water Works Assn.
1946 Conference
St. Louis, May 6 to 10

See for yourself

HOW CALGON* INHIBITS CORROSION PREVENTS SCALE



You are cordially invited to visit the Calgon booth.

* T.M. Reg. U.S. Pat. Off.

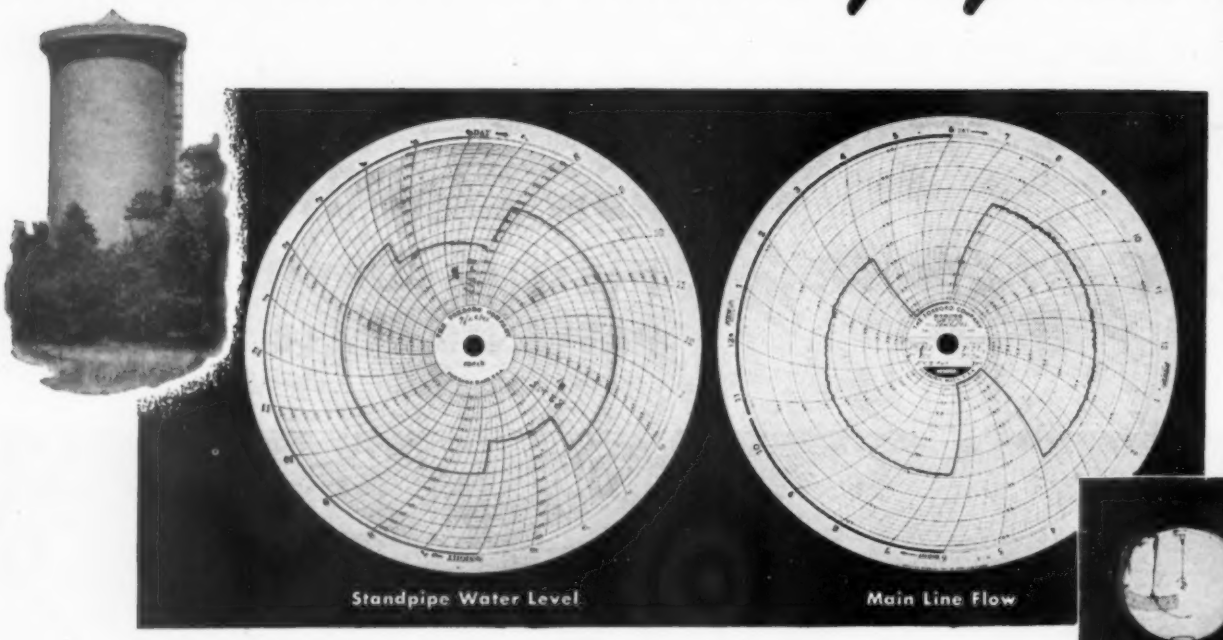
HAGAN
HALL
BUROMIN
CALGON

calgon, inc.

A SUBSIDIARY OF
HAGAN CORPORATION

HAGAN BUILDING
PITTSBURGH 30, PA.

Records like these... pay tribute



GRAPHIC TESTIMONY TO THE EFFICIENCY OF AUTOMATIC PUMPING CONTROL

The charts above are typical 24 hour records of Foxboro Automatic Control in a pumping station supplying water to a New England town of 6000 inhabitants. For several years, such charts have provided an accurate check on pumping costs and on the maintenance of water pressure . . . an important record, incidentally, for securing the best possible municipal insurance rates.

SOLUTIONS TO YOUR PROBLEMS

Practically every pumping station problem of measurement and control is answered by standard Foxboro Instruments. Dependable control, outstanding accuracy and low maintenance are assured by their exclusive, basic features.

Consider the Rotax assembly of the Altitude Controller shown at the right. This extremely simple, positive-operating type of electrical contact translates pressure at the pump house into switch action for operation of the pumps. The measuring element is entirely free and unhampered in movement, insuring maximum sensitivity. Other points of superiority are . . . positive contact at all times with minimum arcing; constant initial and final brush pressures; self-cleaning; platinum contact surfaces; and easy setting. Its built-in relay handles direct operation of valves, auxiliary relays, contactors, small motors for chemical feed and signaling devices.

With over 35 years of on-the-job experience in developing and installing control systems for municipal and industrial use, Foxboro can help you to lay out more efficient, more effective automatic pumping control.

This automatic pumping control system supplies the records shown above. Foxboro Flow Recorder with integrator (top) and Rotax Altitude Controller. Send for copies of Bulletins 200 and 294 describing systems of this type. The Foxboro Co., 142 Neponset Ave., Foxboro, Mass., U. S. A.

FOXBORO
REG. U. S. PAT. OFF.
RECORDING · CONTROLLING · INDICATING
INSTRUMENTS

on guard!

Mathieson
CHEMICALS

Sanitation HTH...Liquid Chlorine...Chlorine Dioxide...Fused Alkali Caustic Soda...Soda Ash...Bicarbonate of Soda...PH-Plus... Ammonia, Anhydrous & Aqua...Dry Ice...Carbonic Gas...Synthetic Salt Cake...Sodium Chlorite Products...Sodium Methylate

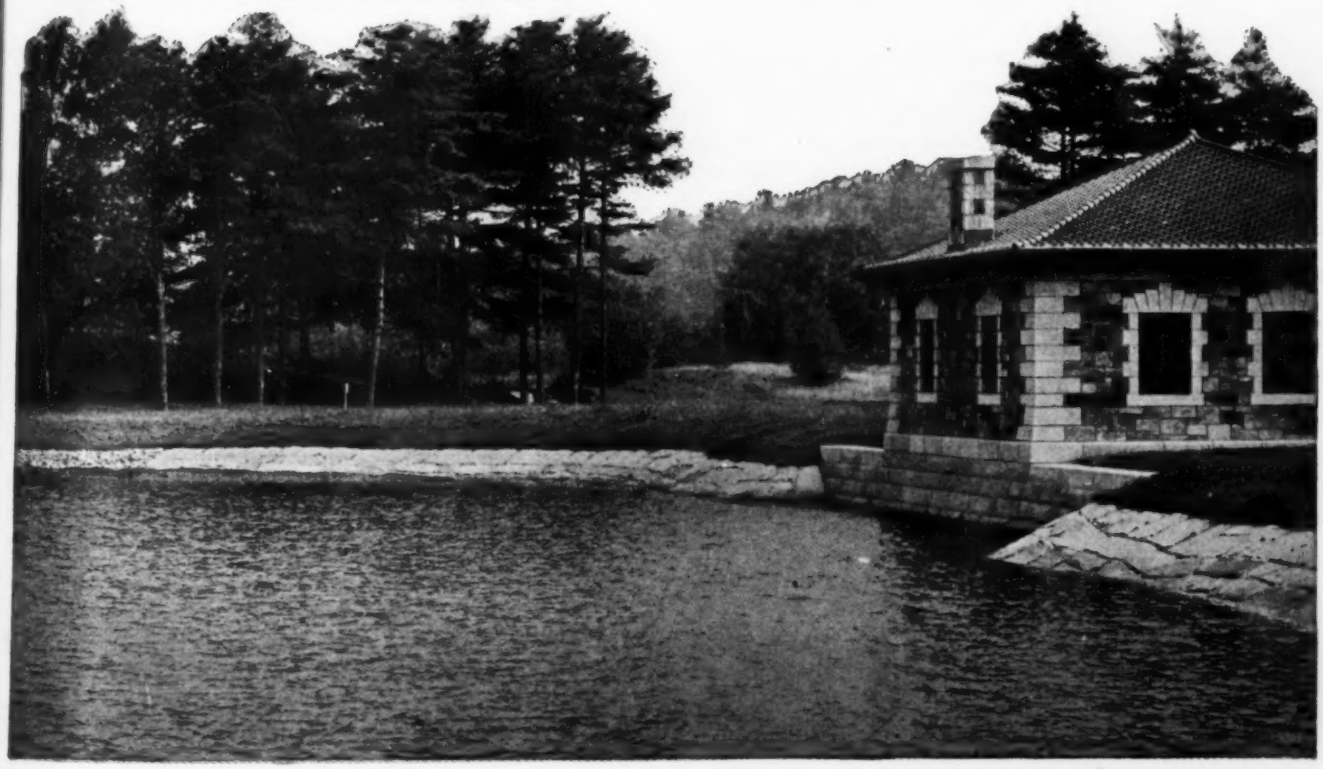
The picture below shows the screen chamber at Weston Reservoir, Weston, Mass., part of the Boston Metropolitan Water Works system, where a supply of Sanitation HTH is wisely kept on hand. For regular and special chlorination jobs, Sanitation HTH is the favorite of progressive water works officials.

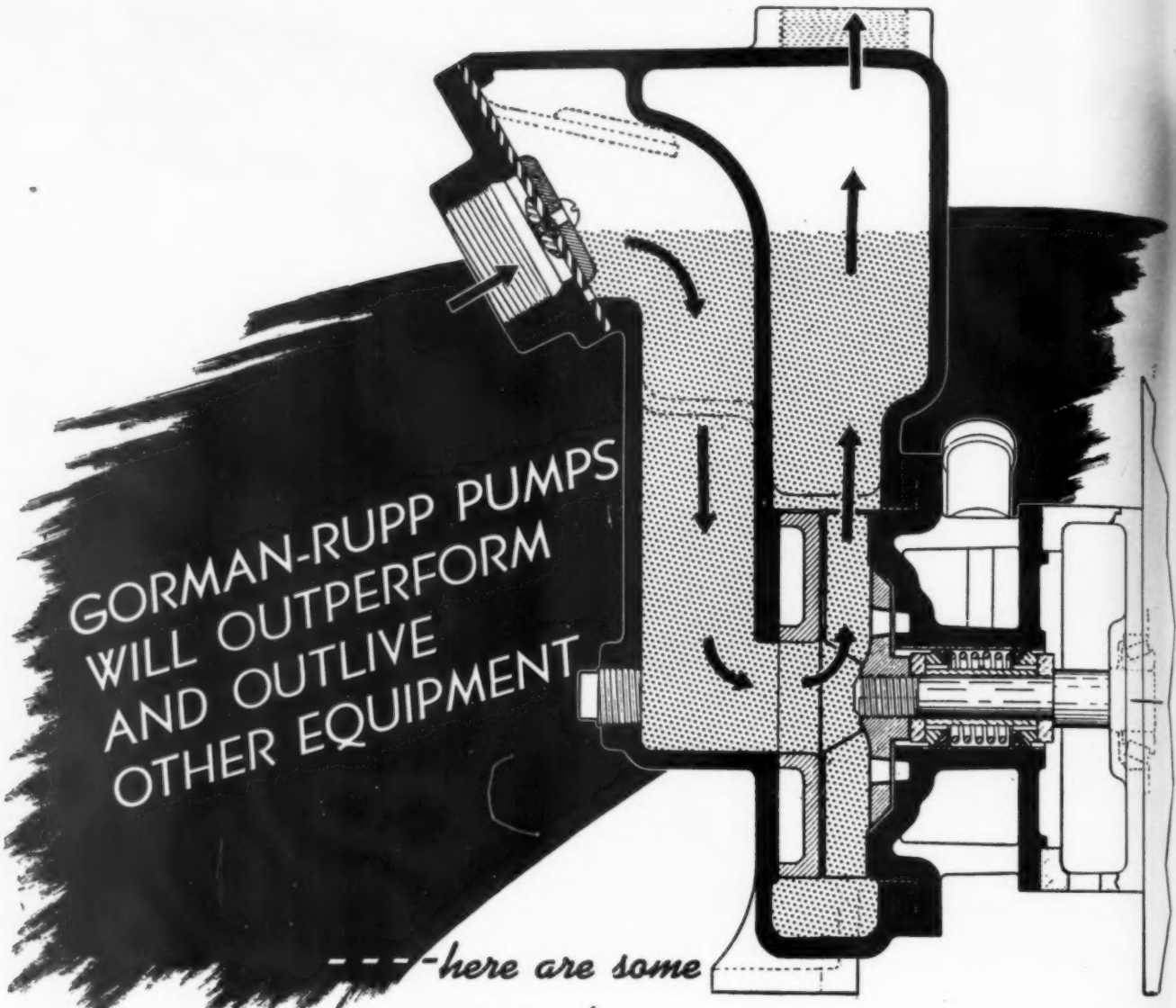
Write for Mathieson's free "Hypo-Chlorination of Water"—a complete reference manual on the use of high-test calcium hypochlorite in the modern practice of safeguarding water supplies.

This valuable, illustrated 80-page manual—in simple, easy-to-read language—covers all stages of standard sanitation practice, including how to use Sanitation HTH in emergencies . . . control of algae . . . sterilizing new mains . . . treatment of filters.

Note: If your regular supplier doesn't have HTH on hand write directly to the Mathieson Alkali Works (Inc.), 60 East 42nd Street, New York 17, N. Y. Get an ample supply today.

THE MATHIESON ALKALI WORKS (INC.)
60 East 42nd Street • New York 17, N. Y.





----here are some reasons why

You can't get the real story of a Gorman-Rupp pump from looking at the outside. It's the simplicity and good design inside that makes this the most efficient, trouble-free pump you can get. *There are no by-passes, no pipes, no valves – nothing to do in priming but start the motor and you start the water. Since such makeshifts rob a pump of as much as 30 per cent of its running capacity, the greater priming simplicity of Gorman-Rupp pumps pays off in more work for less fuel and power.

*Gorman-Rupp pumps are streamlined inside where streamlining counts! Smooth surfaces, no traps and a design that flows with the water adds another big factor to efficiency and prevents clogging. These pumps will handle any muck or solids that will pass the intake and clear them out of the pump body.

*The G-R impeller operates at motor speed, without reduction gears – another source of wear, trouble and maintenance eliminated. This impeller is the only moving part and rotates on high grade roller bearings.

*Every part of a Gorman-Rupp pump has long wear built into it, and every wearing part is replaceable without tearing the pump apart. This maintenance can be done by an unskilled man with common tools.

These are a few reasons why Gorman-Rupp self-priming centrifugal pumps will out-perform and outlive any other comparable equipment. Write for further detailed information.

THE GORMAN-RUPP COMPANY

GORMAN-RUPP PUMPS — UNSURPASSED FOR PUMPING FAST

327 BOWMAN STREET • MANSFIELD, OHIO

Personal pride in PRECISION PRODUCTION

WITH the pride of watchmakers, Badger craftsmen produce the many precision parts used in Badger Water Meters. That is one reason why years of accurate metering are yours when you use Badger Meters.

Send us the coupon. It will bring a Badger Meter Engineer who will show you all the reasons why you get "More for your money," when you buy Badger Water Meters.

BADGER METER MFG. CO.
MILWAUKEE 10, WISCONSIN

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BADGER METER MFG. CO. • MILWAUKEE 10, WISCONSIN

☐ Please have a Badger Meter Representative call.
☐ Please send complete descriptive literature.

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Individual_____ Title_____

Street Address_____

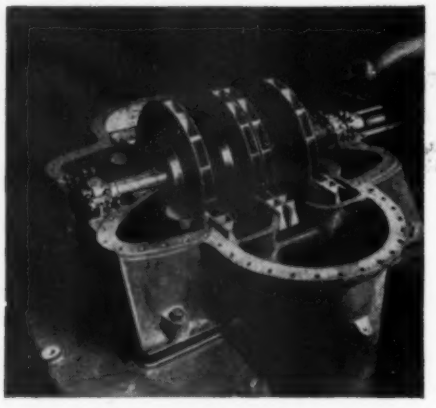
City and State_____

Question: In a Water Works or Sewerage Project, Are You Looking For

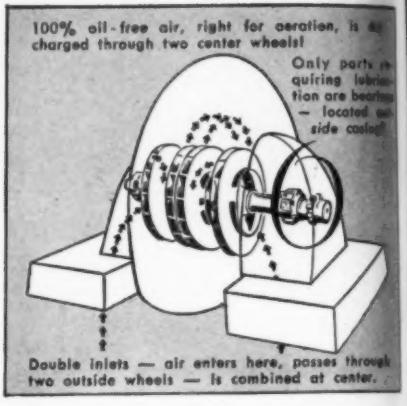
KNOW HOW?

WHAT KIND—BLOWERS, COMPRESSORS, VACUUM PUMPS, SLUDGE DEWATERING EQUIPMENT, WATER OR SEWAGE PUMPS, MOTORS, CONTROL?

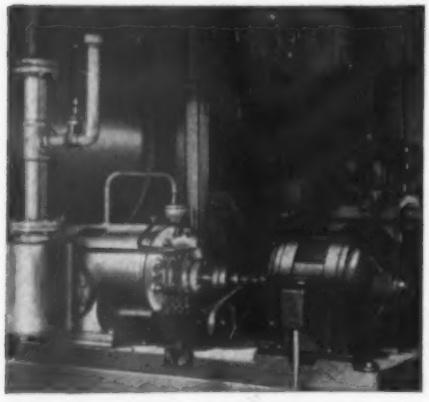
1 Whichever it is, A-C can help! Example: midwest activated sludge plant needed 100,000 cfm air at 10 lb G. Two 2450 hp turbine driven, 50,000 cfm Turbo-Blowers supply it. Double inlet type...



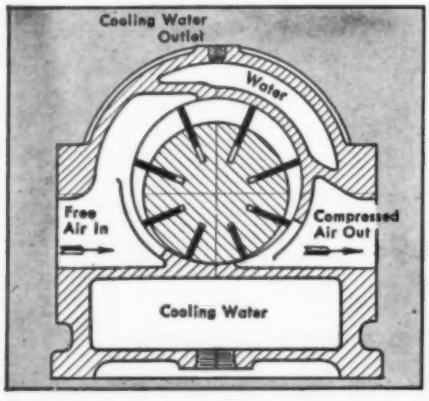
2 Each is in effect 2 blowers in same casing. Half volume enters each end, all discharges at center. Wheels are doubled, but smaller diameter. Result: higher operating speed for turbine drive.


100% oil-free air, right for aeration, is discharged through two center wheels!
Only parts requiring lubrication are bearings — located outside cooled
Double inlets — air enters here, passes through two outside wheels — is combined at center.

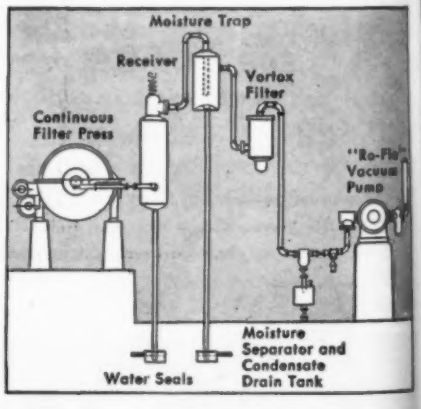
3 Simple, isn't it? *No* reciprocating parts — movement *completely* rotary. *No* rubbing parts; *no* lubrication except at *outside* bearings. That means oil-free air—right for aeration! Bulletin B6104.



4 Plan to dewater sludge mechanically? "Ro-Flo" *Vacuum* Pumps produce vacuums high as 28½" mercury. Will you capture and store digester gases? Use "Ro-Flo" *Compressors*. Bulletin B6211.

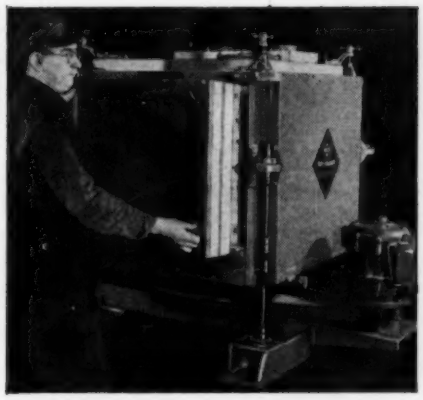


5 Both operate on sliding vane principle. Blades in rotor are *free to move* radially in and out of slots. Result: multiple longitudinal cells which efficiently trap air in compression stages.

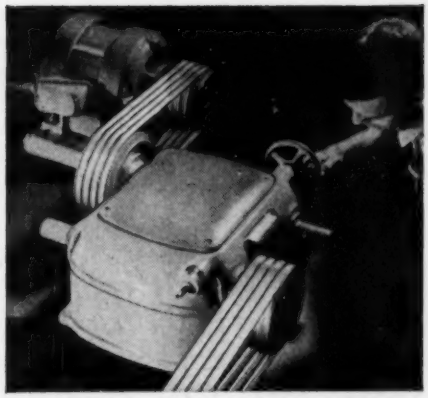


6 Combination of "Ro-Flo" vacuum pump and continuous filter press *removes up to 25% moisture* in initial dewatering of sludge for incineration, or for manufacture of fertilizer.

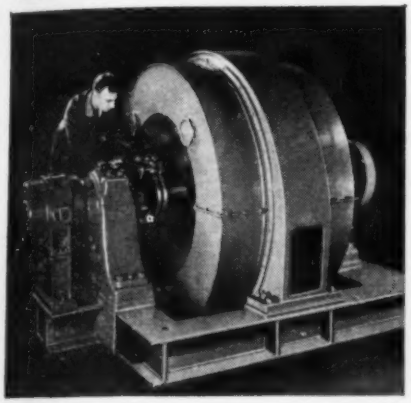
7 After that, *drying.* Here, A-C rotary kilns reduce moisture content to low %! A-C kilns are all-welded, have centralized control, features which reduce fuel consumption and operating costs.



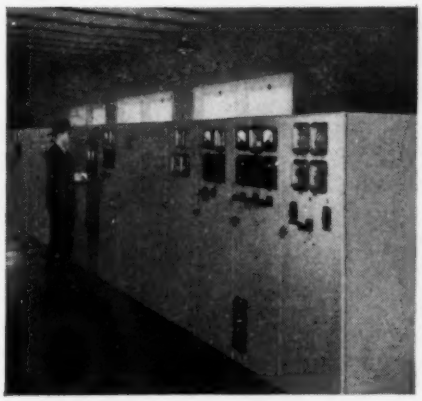
8 In final preparation of commercial fertilizer still other A-C equipment is used — "Pulverators", vibrating screens, gyratory sifters (see above) are used in manufacture of well-known brands.



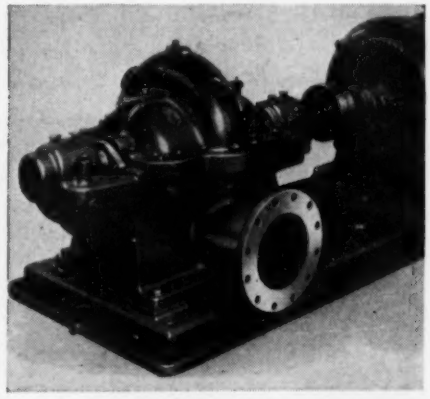
9 Member of A-C's great Texrope "team" is Vari-Pitch Speed Changer. On sludge pumps, machines—*wherever* you need speed *range* — it provides infinite changes — ratio of 3.75 to 1.



10 A-C not only builds 101 kinds of *basic* equipment for *you,* but also the power to *drive* it — motors, turbines, gasoline engines . . . gives you "machine teamwork"!



11 A-C's wide line of control permits *flexible* circuit design —makes tough problems look simple! Here, switchgear in typical pumping station layout controls motors, pumps.



12 Got a pump problem? A-C can furnish pumps of *any* capacity or head you require! Offers famous Type "S" water, sewage, storm water, fire and other pumps!

PUT THIS EXPERIENCE TO WORK!

A-C offers Water Works and Sewerage men, and their consultants, *practical* help on engineering problems — through a "Cooperative Engineering" service second to none — and that's backed by one of the *broadest lines* of major Public Works equipment!

A 1923

ALLIS-CHALMERS

PRODUCER OF THE WORLD'S LARGEST LINE OF MAJOR INDUSTRIAL EQUIPMENT!

A-C

MILWAUKEE, WISCONSIN

See What HOMELITE Portable Pumps and Generators will do on paper

Two new bulletins . . . L501 on Homelite Portable Pumps and L406 on Homelite Portable Generators . . . will bring you up-to-date on all the latest developments in Homelite design and performance. Send for these two bulletins. Look them over carefully. *But don't stop there.*

then see what they'll do on the job

Homelite Representatives, now located in strategic centers throughout the country, are ready to give actual on-the-job demonstrations of Homelite pump and generator performance. Let them give one for you. Let them show you all the pumping qualities of Homelite Portable Pumps. Let them show you the new Homelite Portable Generators in action . . . running floodlights or all kinds of electric tools . . . on *your* job, any place, any time. Simply write.

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CORPORATION
Portable Pumps, Generators, Blowers
PORT CHESTER, NEW YORK

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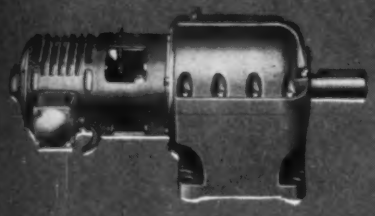
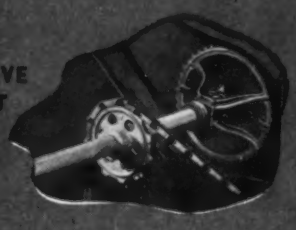
COMPLETE TECHNICAL INFORMATION ON EQUIPMENT AND PLANT DESIGN



SINGLE TANK DRIVE UNIT
(ALSO DOUBLE UNITS)

ASSEMBLED
SELF ALIGNING
BEARING AND
HOUSING



OFFSET DRIVE
SPROCKET

GIVE YOUR PROBLEM TO JEFFREY

Whether it calls for supplying equipment for a complete plant or for revamping and improving your present installation, Jeffrey has the answer in efficient and modern equipment for water and sewage treatment.

Shown here is a typical sludge collector installation and a few of its details. Jeffrey makes bar screens, screenings and garbage grinders, grit collectors, grit washers, chemical feeders, floctrols, equipment for biofiltration plants, and general conveying equipment.

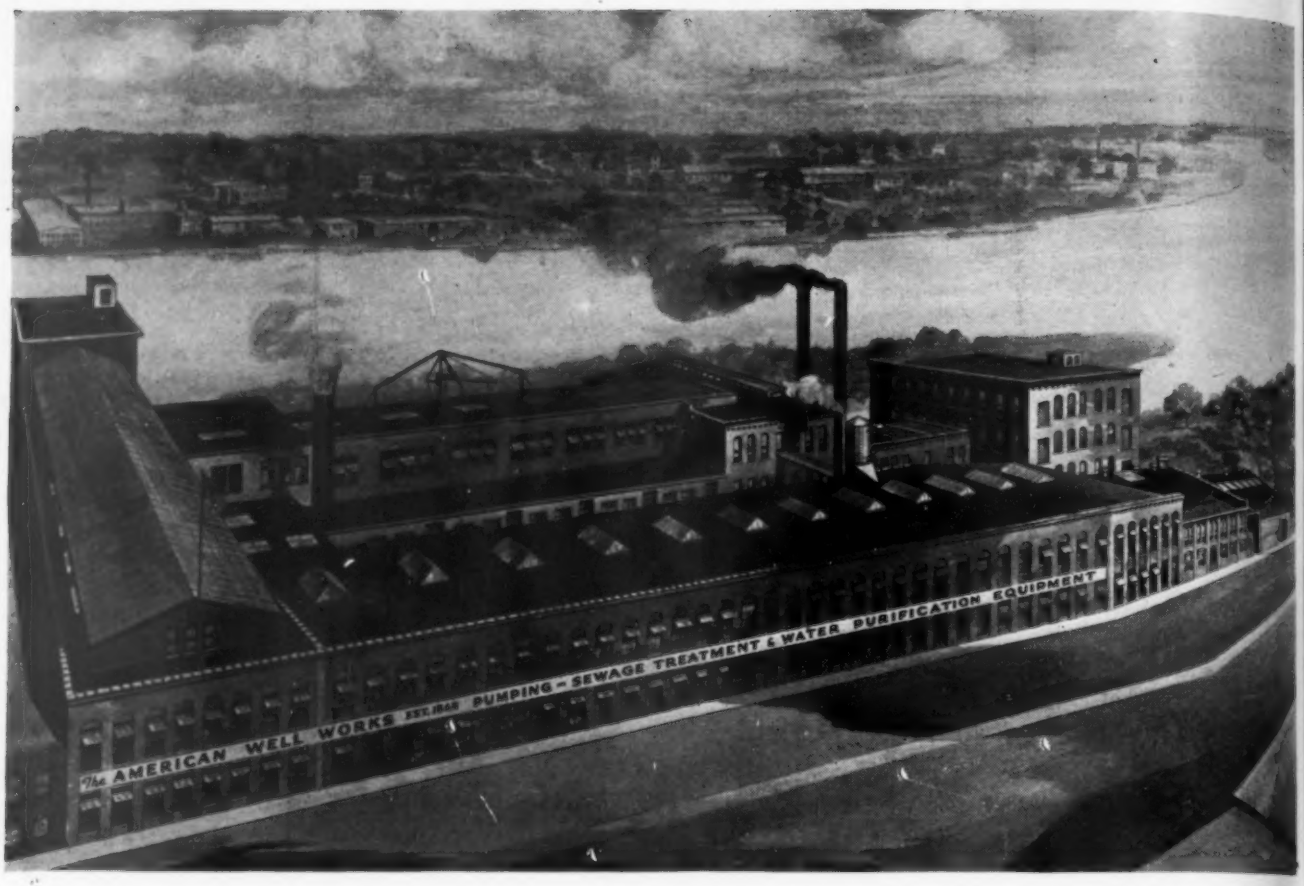
(PATENTED)

ATTACHMENT
TO GIVE
FULL DEPTH
SUPPORT
TO FLIGHT

JEFFREY

ESTABLISHED 1877

JM



THE AMERICAN WELL WORKS

MANUFACTURERS SINCE 1868

• PUMPING MACHINERY •

• SEWAGE TREATMENT •

• WATER PURIFICATION •

78 YEARS CONTINUOUS OPERATION

• INTEGRITY

QUALITY

DEPENDABILITY •

• RESEARCH

• ENGINEERS

• MANUFACTURERS

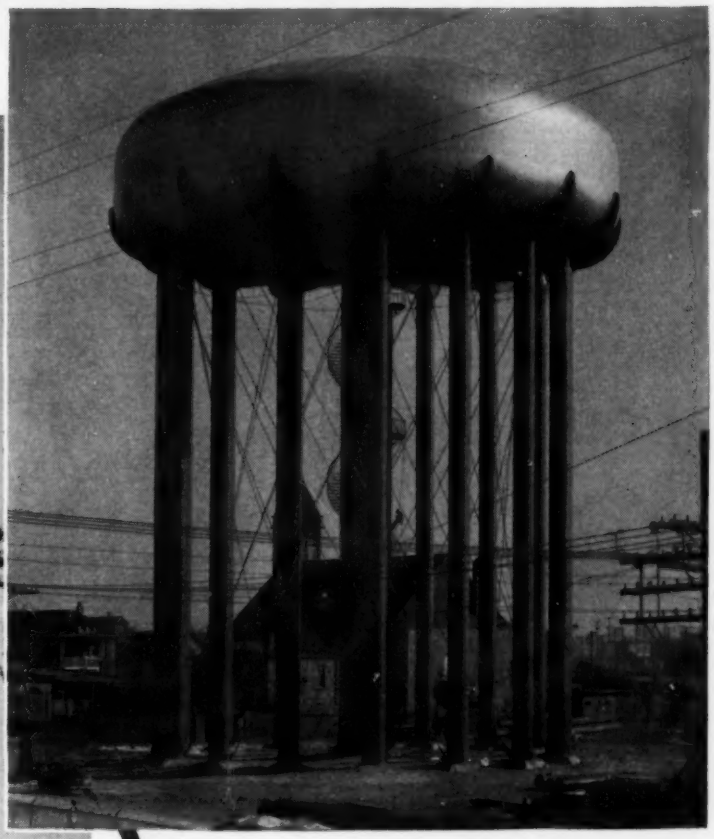
THE AMERICAN WELL WORKS

FACTORY AND LABORATORIES

AURORA, ILLINOIS

Gary, Indiana TURNS TO HORTON ELEVATED STORAGE

. . . to solve a pressure problem in the outlying districts of its distribution system.



For years Gary has pumped its water *direct* from Lake Michigan. At peak load periods water pressure in the outlying districts dropped as low as 6 lbs. per sq. in. This was due partly to higher elevation and also to the fact that the meters were at the extreme end of the line. To remedy the situation, the Northern Indiana Public Service Company installed two Horton elevated tanks . . . a 1,500,000-gal. tank, shown above, and a 750,000-gal. tank shown at the left. In addition to solving the pressure problem, it is expected that these tanks will relieve the strain on the pumping equipment during the peak load periods. The average daily consumption at Gary during the first quarter of the year is about 12,000,000 gals. During the summer months this increases to approximately 23,000,000 gals. per day.

ENGINEERING DATA REGARDING GARY WATER DISTRIBUTION SYSTEM

Source of water—Lake Michigan
Miles of mains—180
Size of mains—2 in. to 30 in.
Number of meters in system—17,000
Number of fire hydrants—1,015
Area served—44 sq. miles
Average daily consumption (1st quarter of year)—12,000,000 gals.
Average daily consumption (summer months)—23,000,000 gals.

CHICAGO BRIDGE & IRON COMPANY

Chicago 4.....2198 McCormick Bldg.
New York 6.....3390-165 Broadway Bldg.
Cleveland 15.....2262 Guildhall Bldg.
Los Angeles 14.....1455 Wm. Fox Bldg.
Birmingham 1.....1586 North 50th Street
Atlanta 3.....2181 Healey Bldg.
Tulsa 3.....1646 Hunt Bldg.
Houston 1.....5615 Clinton Drive
Philadelphia 3.....1644-1700 Walnut Street Bldg.
Washington 4.....703 Atlantic Bldg.
San Francisco 5.....1283-22 Battery St. Bldg.
Detroit 26.....1551 Lafayette Bldg.

Plants in Birmingham, Chicago and Greenville, Pa.

In Canada: Horton Steel Works, Limited, Fort Erie, Ont.

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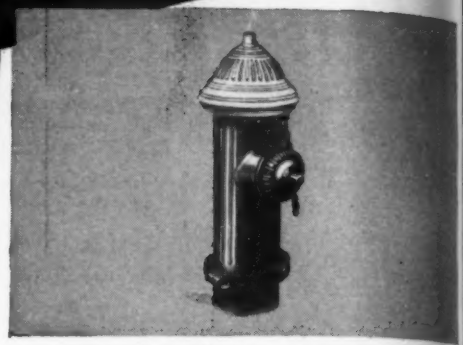
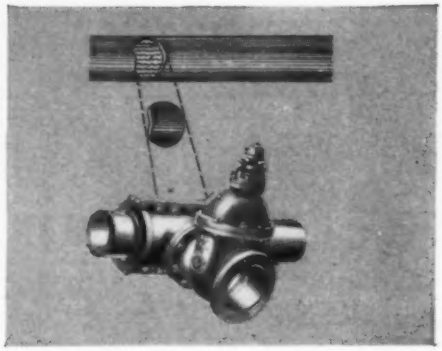
THE SMITH LAUREL LEAF

when in need of . . .

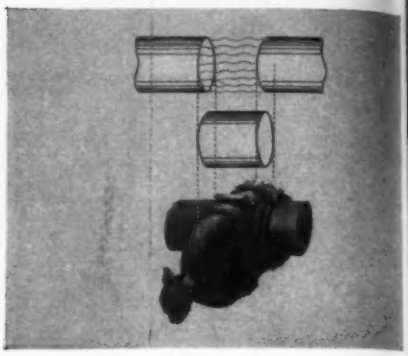


Fire Hydrants, **of the compression type, featuring Protectop collision protection, frost-proof tapered barrel, and positive action drain.**

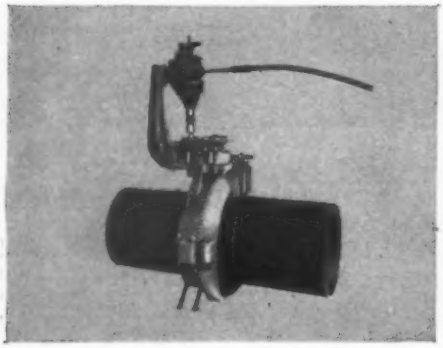
Gate Valves, **for low, medium or high pressure service. Manual, hydraulic cylinder, or motor operation.**



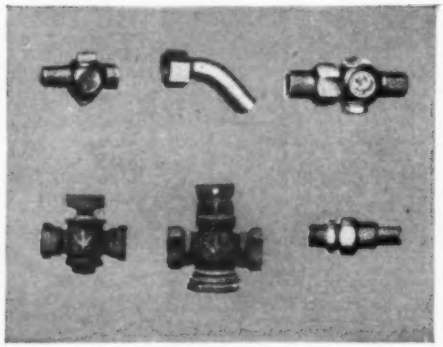
Tapping sleeves, **for making branch connections (in sizes 2" thru 42") under pressure in cast iron, steel, asbestos-cement or reinforced concrete pipe of any size.**



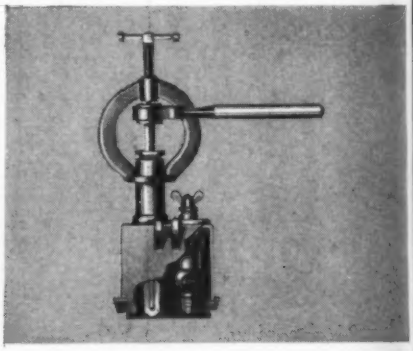
Inserting Valves, **for installing valves under pressure in cast iron, steel or asbestos-cement pipe in sizes 4" thru 48".**



Pipe Cutting Machines. **With the SMITH machine a true "lathe" cut can be made on cast iron, steel or asbestos-cement pipe in a minimum time.**



Water service brass goods: **corporation —curb cocks, couplings and other fittings for copper tube, lead and iron pipe services.**



Corporation Tapping Machines. **With the SMITH Tapping Machines corporation cocks can be installed under pressure. The machine is compact and easy to operate.**

**** Water works material of proven quality***

13

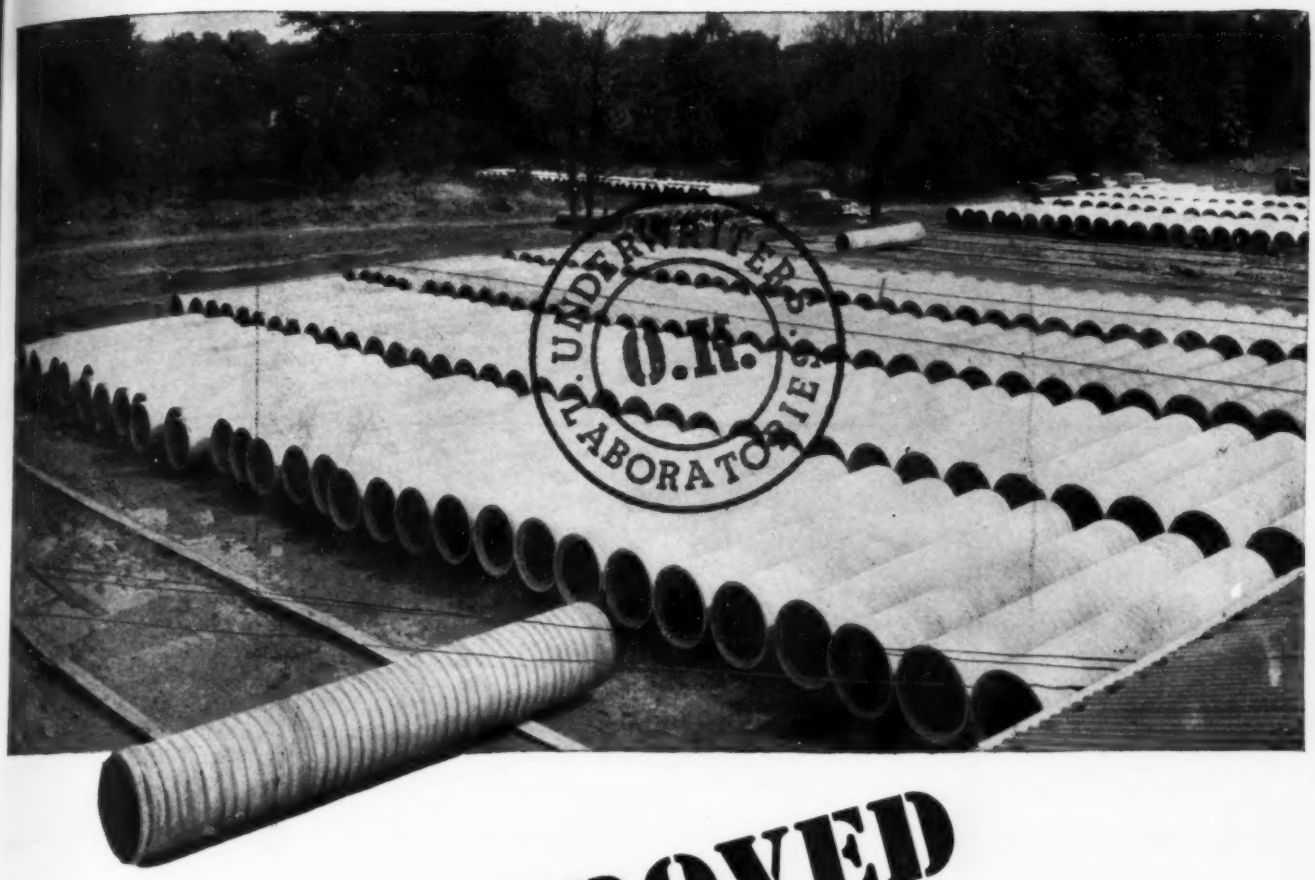
FIRE HYDRANTS
GATE VALVES
CHECK VALVES
INSERTING VALVES
TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

FLOOR STAND
INDICATOR POST
TAPPING MACHINE
INSERTING MACHINE
PIPE CUTTING MACHINE
CORPORATION TAPPING MACHINE

WHEN AT THE WATER WORKS CONVENTION YOU ARE CORDIALLY INVITED TO VISIT BOOTH NO. 56 OF THE A. P. SMITH MANUFACTURING COMPANY.



APPROVED

....by Underwriters' Laboratories

● On November 24, 1944, after rigid tests and exhaustive investigation, Underwriters' Laboratories, Inc., sponsored by the National Board of Fire Underwriters, recommended to the Fire Council of Underwriters' Laboratories, Inc., the acceptance of Lock Joint Prestressed Concrete Cylinder Pipe of the 150 lb. class in sizes from 20" to 42" for use in public and private waterworks and fire service systems. This recommendation was accepted December 21, 1944.

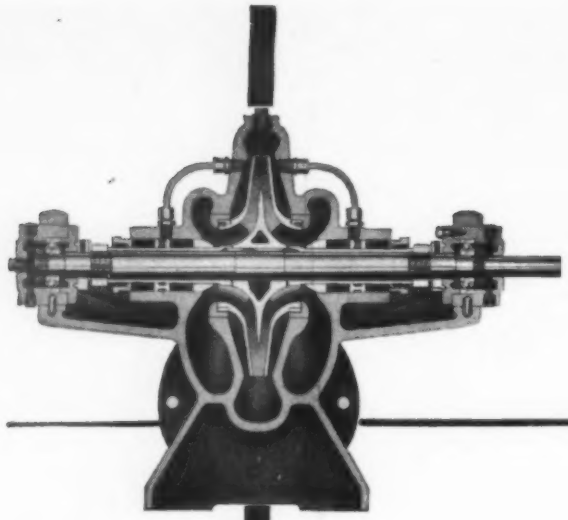
LOCK JOINT PIPE COMPANY

Established 1905

P. O. BOX 269, EAST ORANGE, NEW JERSEY

Denver, Colo. • Chicago, Ill. • Kenilworth, N. J. • Kansas City, Mo. • Rock Island, Ill. Joplin, Mo. • Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. • Navarre, Ohio

SCOPE OF SERVICES Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains in a wide range of diameters as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.

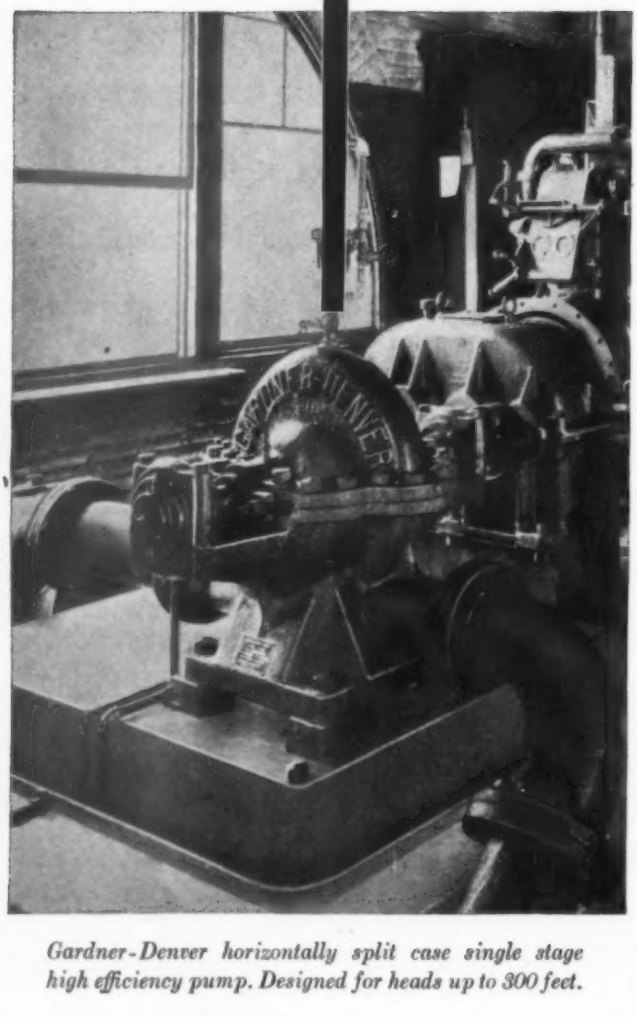


The Inside Story of a *Better Pump*

Look inside a Gardner-Denver horizontally split case double suction centrifugal pump. Then it's easy to see why these pumps have high efficiency—why they frequently save enough in power costs to pay for pump and motor within a single year!

Water passages are properly proportioned to produce an even, uniform flow of water through the pump. Cartridge type bearing housings protect the ball bearings. The cast bronze parts are all high tensile hard bronze—impeller shaft sleeves are hard bronze. Shafts are made of high carbon alloy steel, having a tensile strength in excess of 100,000 pounds per square inch. Cast iron used in this pump has a tensile strength above 40,000 pounds per square inch.

Backed by 87 years of Gardner-Denver manufacturing experience, Gardner-Denver centrifugals will prove their greater worth in your installation. For complete information, write Gardner-Denver Company, Quincy, Ill.



Gardner-Denver horizontally split case single stage high efficiency pump. Designed for heads up to 300 feet.

ENGINEERING QUALITY ... SINCE 1859

GARDNER-DENVER

Since 1859

Thoroughbreds "Pay Off"

. . . . IN ENDURANCE AND TOP PERFORMANCE

Though meters can be purchased at lower cost, this Builders precision instrument is a *best buy* because:

- Long life makes cost per year extremely low. Builders Herschel Standard Venturi Tubes and Type M Register-Indicator-Recorders are functioning with original accuracy after more than thirty years' service.
- Low head loss means efficiency. Reduced pumping costs pay dividends every day in the year. Useful head on gravity systems is conserved.
- Trouble-free design—no moving parts in pipe line; no shutdown during maintenance or adjustment.
- The high accuracy and wide range of the Type M Register-Indicator-Recorder contribute to greater efficiency in plant operation. Results averaging better than plus or minus two per cent over flow range as wide as 1 to 15 or more are readily obtained.

For Bulletin 293-C, address Builders-Providence, Inc., (Division of Builders Iron Foundry), 10 Codding Street, Providence 1, Rhode Island.

Builders Type M Venturi Instrument and Herschel Standard Venturi Tube. Short Venturi Tube also available.

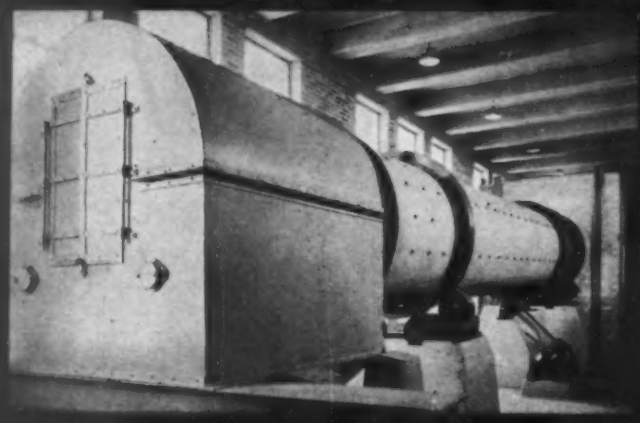
BUILDERS PRODUCTS

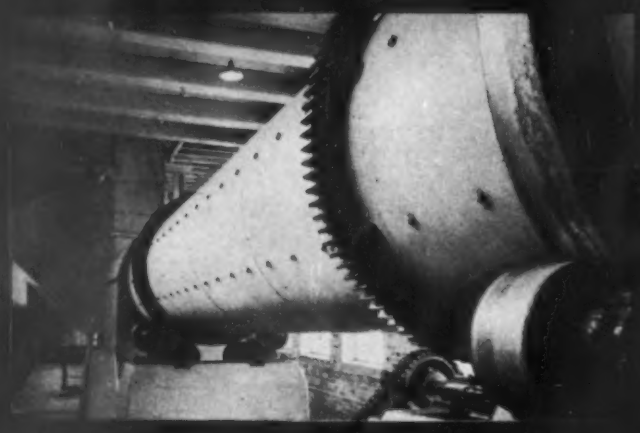
Venturi, Propeloflo and Orifice Meters • Type M and Flo-Watch Instruments • Filter Controllers and Gauges • Master Controllers • Kennison Nozzles • Chronoflo Telemeters • Builders-Chronoflo Conveyor Scales

BUILDERS

BUILDERS-PROVIDENCE

General American Louisville
ROTARY DRYERS





Louisville Rotary Dryers, as designed and built by General American, offer a continuous, efficient and economical means of drying municipal wastes such as sludges, screening and garbage.

In all Louisville Rotary Dryers, the material to be dried is fed continuously into one end of the dryer cylinder, is tumbled in either direct or indirect contact with the heating medium and discharge — also continuously, and at the desired dryness, — from the opposite end of the machine.

General American maintains laboratories and pilot plants in order to determine and recommend the correct type of drying equipment. In some instances, entirely new drying techniques have been developed for materials which have formerly baffled all attempts to rotary continuous drying.

Other General American Products

Sludge Gas Holders
Turbo-Mixers
Sludge Filters
Tanks • *Stacks*

General American
TRANSPORTATION CORPORATION
process equipment • steel and alloy plate fabrication

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LE ROI
MILWAUKEE
Over $27,000 net saving in 7 years . . . with these LE ROI Engine-Generator units operating on "no-cost" Sewage Gas
In the Oshkosh, Wisconsin, Municipal Sewage Treatment Plant, two Le Roi Engine-Generator units paid for their original cost in one year—and saved this city over $27,000 in 7 years—by operating on "no-cost" sewage gas.
During this 7-year period, the public utility charge for 1,866,350 KWHrs. would have been $37,205.03. The actual cost of this same power generated by two Le Roi units was $9,484.26 . . . a saving of $27,720.77 . . . or a net cost of only ½ cent per KWH.
If sewage gas is available at your plant, simply send us the B.t.u. content and the cu. ft. available per hour, and Le Roi engineers will work out a practical, money-saving program. The necessary compression and carburetion are readily arranged. Write for bulletins.
LE ROI Company • 1726 S. 68th Street, Milwaukee 14, Wisconsin
No. 1
LE ROI
LE ROI
LE ROI
LE ROI

TURN THE PAGE

A model 105 Le Roi Compressor speeds this sewer repair job so that traffic can be resumed as quickly as possible.

. . . many municipalities tell us LE ROI "can't be beat" for rush maintenance work

Team up a Le Roi Portable Air Compressor with the rest of your equipment — and a few weeks will prove the tremendous value of this unit in speeding the completion of any job requiring the use of air-driven tools.

There are many reasons why Le Roi portable air compressors have achieved their world-wide reputation for thoroughly dependable air power — *they are the only air compressors built by a leading manufacturer of industrial engines.* The result is your four-way benefit: (1) Your compressor is built to the precision standards of an engine builder. (2) You get smoothness of operation. (3) You get the economy of assembly line production. (4) You get balanced, coordinated engineering and design.

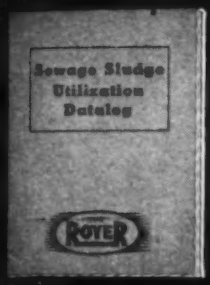
LE ROI
MILWAUKEE

The accumulated result to you is dependable, economical air power, to speed your schedules and establish your reputation for "on-time" job completions. Sizes to fit all your requirements range from 60 to 315 c.f.m., powered by Le Roi gasoline engines, and 105 to 500 c.f.m., powered by full-diesel engines. See your Le Roi distributor or write for additional information today.

LE ROI COMPANY • 1726 So. 68th St., MILWAUKEE 14, WISCONSIN

New York • Washington • Birmingham • Tulsa • San Francisco

EVEN IF YOU GIVE YOUR SLUDGE FERTILIZER AWAY—YOU'RE MONEY AHEAD



The cost of converting your sewage sludge into a valuable fertilizer is definitely less than the cost of incinerating or burying it. Incineration calls for a capital investment for the incinerator, often special drying equipment, as well as labor and fuel. Burying requires trucking, considerable labor, and frequently payment for the use of a burial site.

Less manpower is needed to produce fertilizer with the Royer Sludge Disintegrator than either burying or incinerating, and these inexpensive machines withstand years of abusive service.

One man operates the Royer, and all that need be done is to shovel the sludge cake into the hopper. The Royer does all the rest, and it will handle sludge cake containing up to 60% moisture. The Royer thoroughly shreds, mixes, aerates and further dries the sludge. Sticks, stones and trash are automatically removed. The machine discharges onto pile or truck an effective, ready-to-use fertilizer.

Even if this fertilizer is given away, you would be money ahead, as compared with the cost of incineration or burial. However, very little of the huge volume of fertilizer produced by Royers is given away. Sewage works using Royers find a ready market for their fertilizer, especially among growers of food crops. *What was formerly an expense item, is thus converted into a permanent source of revenue!*

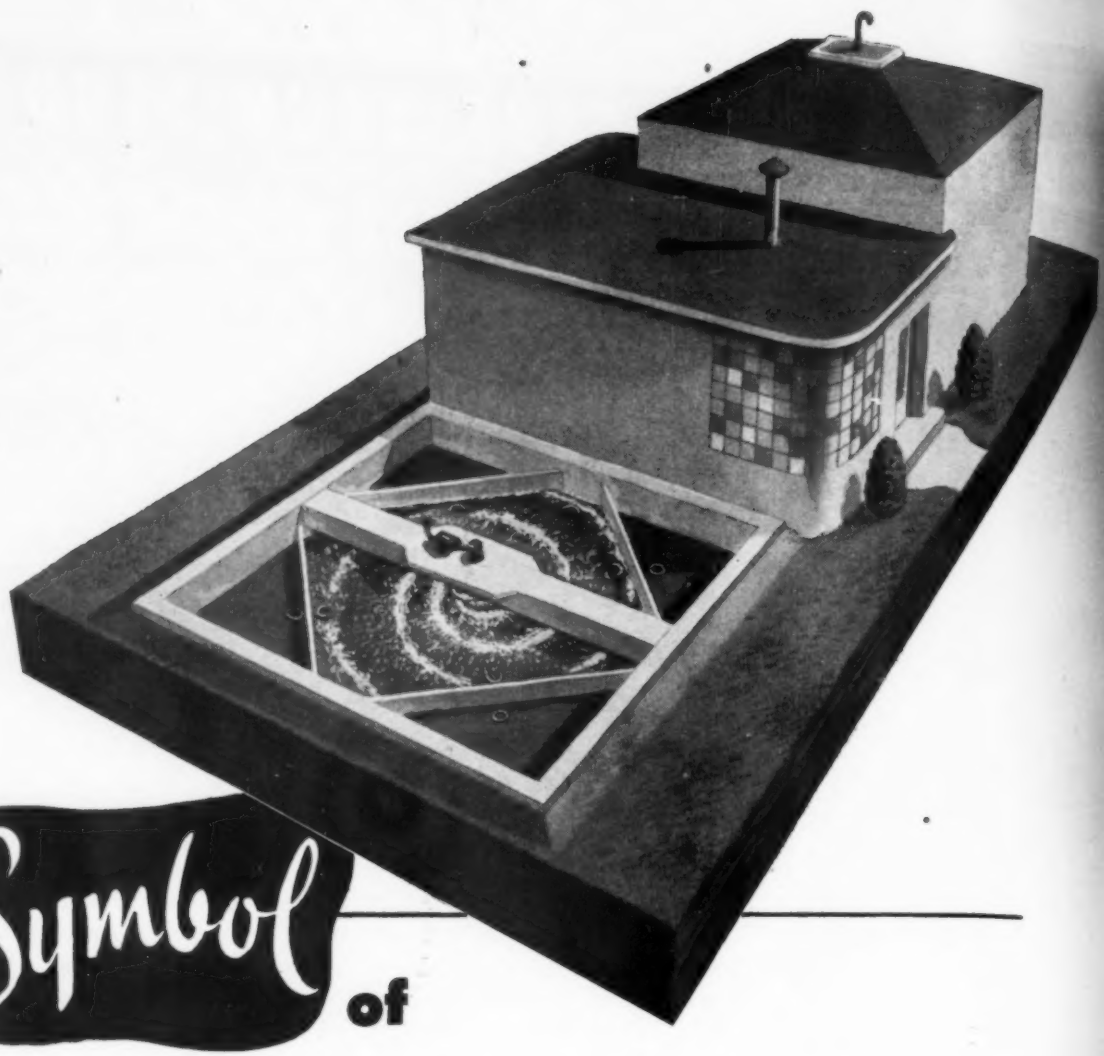
Twelve models—electric motor, gasoline engine or belt-to-tractor driven. All these are shown in our Sewage Sludge Utilization Datalog, which also contains comprehensive information on the fertilizing value of sewage sludge. Your copy awaits your request.

ROYER

PIONEERS IN THE SALVAGE OF SEWAGE SLUDGE

ROYER FOUNDRY & MACHINE CO.

170 PRINGLE ST., KINGSTON, PA.



Symbol of a Community with the RIGHT IDEA

Aeration and final sedimentation in a single concrete structure of minimum dimensions . . . simple, smartly modern, proved efficient: that is the Yeomans "Aerifier" Package sewage treatment plant.

Tailored and "packaged" to fit specific needs, Yeomans "Aerifier" produces crystal clear effluent at exceptionally low over-all plant cost. It is ideal for small communities up to 3000 persons, and for isolated institutions and industrial plants.

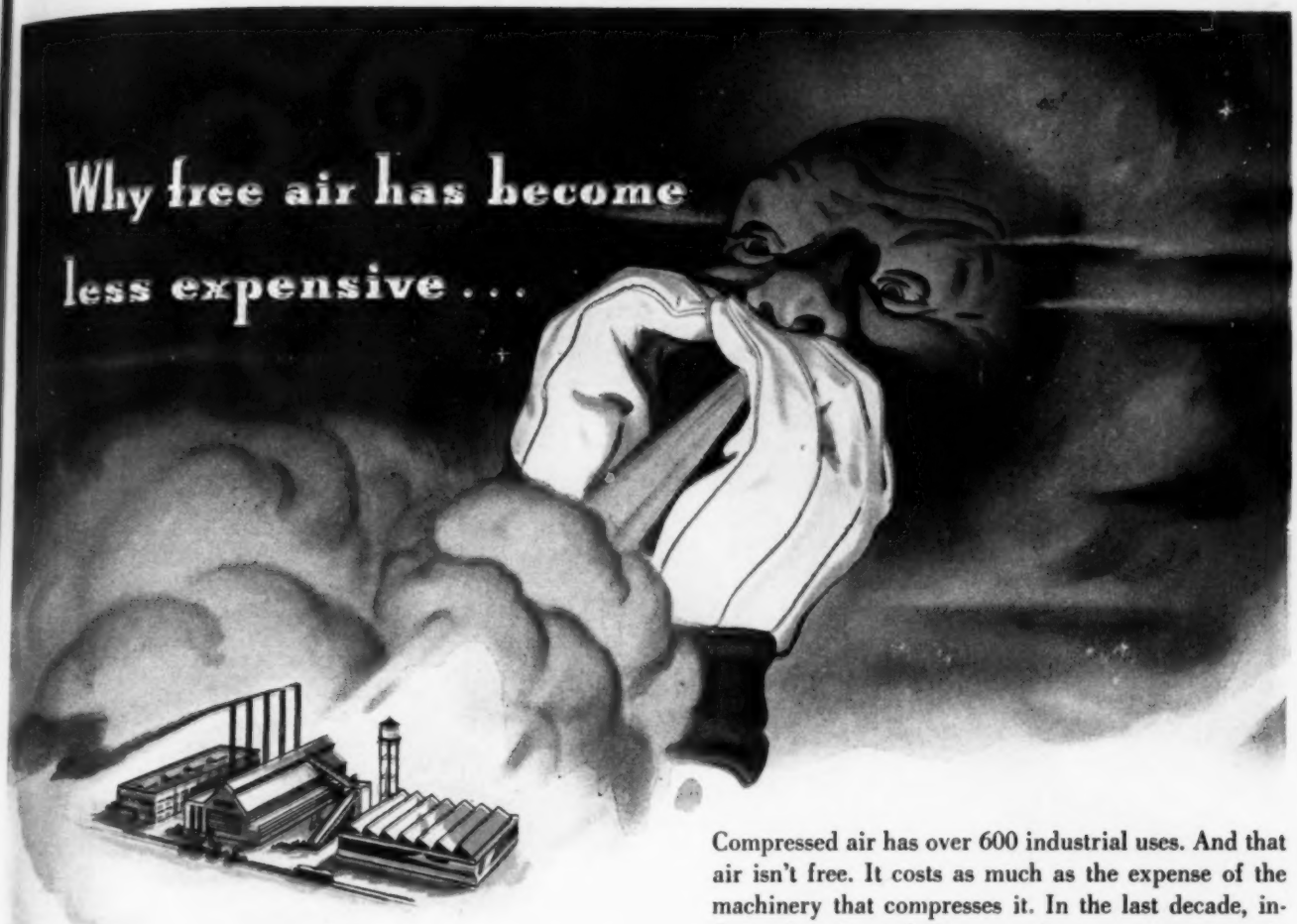
Operation is simplified to a daily routine check. All units are open for visual inspection . . . clean, free from odors.

Yeomans "Aerifier" installations include final adjustment, initial factory operation, and thorough training of operators. And Yeomans engineering counsel is always available.

A complete recommendation with construction cost estimates and application engineering will be furnished promptly on request.

Yeomans Brothers Company

1423 NORTH DAYTON STREET • CHICAGO 22, ILLINOIS



Compressed air has over 600 industrial uses. And that air isn't free. It costs as much as the expense of the machinery that compresses it. In the last decade, industry has demanded more and more compressed air until now air as an industrial material is consumed by the millions of tons. It takes more than a ton of air to melt a ton of iron; more than 400 pounds of air to spray a pound of paint.

Dresser Industries is constantly at work engineering down the cost of moving air. And what goes for air goes for any other gas. Whatever the job calls for—millions of cubic feet of natural gas at 2,000 pounds per square inch for putting the final squeeze on an exhausted oilwell, or a precisely measured stream of air for supercharging—Dresser has engineered the right type of equipment.

It may be a Clark compressor built on the "Angle" principle to deliver more horsepower per unit of space than any other gas engine-driven compressor; it may be a Roots-Connersville Rotary Positive Blower engineered with such ingenious simplicity that there is virtually no maintenance needed; or an R-C Centrifugal, if that's what's needed. And, in every case, there is Dresser Manufacturing Division's unique flexible pipe coupling that prevents leakage caused by vibration in air lines.

If air or any other gases are to be moved, or compressed, Dresser Industries, Inc., can do it at lower cost with equipment that is *First to be new—Last to wear out.*

BOVAIRD & SEYFANG Manufacturing Co., Bradford, Pa.

BRYANT Heater Company, Cleveland, Ohio

CLARK Bros. Co., Inc., Olean, New York

DAY & NIGHT Mfg. Co., Monrovia, Calif.

DRESSER Manufacturing Div., Bradford, Pa.

DRESSER Manufacturing Company, Limited, Toronto, Ont., Canada

INTERNATIONAL Derrick & Equipment Co., Columbus, Marietta & Delaware, Ohio; Beaumont, Texas; Torrance, Calif.

KOBE, Inc., Huntington Park, Calif.

PACIFIC Pumps, Inc., Huntington Park, Calif.

PAYNE Furnace Co., Beverly Hills, Calif.

ROOTS-CONNERSVILLE Blower Corporation, Connersville, Ind.

SECURITY Engineering Co., Inc., Whittier, Calif.

STACEY BROS. Gas Construction Company, Cincinnati, Ohio

VAN DER HORST Corp. of America, Olean, N. Y. and Cleveland, O.

Creative Engineering
FOR GENERAL INDUSTRY

DRESSER INDUSTRIES, INC.

TERMINAL TOWER · CLEVELAND 13, OHIO

Geared to anticipate the course of industry
Oil and gas equipment a specialty

You can
LAY WATER PIPE FASTER
when it's easy-to-handle Transite

KEEPING UP with the trenching machine is common practice when the pipe being installed is Transite!

Crews can unload and install this easy-to-handle, asbestos-cement pipe quickly . . . lay all but the larger sizes without mechanical handling equipment. The Simplex Coupling cuts assembly time . . . assures tight, yet flexible joints.

And in addition, Transite delivers these *long-term* advantages:

No tuberculation. Made of asbestos and cement, its initial high flow rate (C=140) is unaffected by tuberculation. Users never have to contend with excessive pumping costs resulting from this costly form of internal corrosion.

High corrosion resistance—outside, as well as inside and all the way through! Thousands of Transite Pipe installations—many in highly aggressive soils—testify to its exceptional resistance to soil corrosion.

Low maintenance. Transite's tight joints, high uniform strength, great durability and proved corrosion resistance all add up to low maintenance. Over the years, Transite Pipe has established an enviable record for economy in water distribution and supply lines throughout the country.

For complete information, write for brochure TR-11A. Johns-Manville, Box 290, New York 16, New York.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville
TRANSITE PRESSURE PIPE
An Asbestos Product

WE'RE NOT GOING TO A FIRE... WE'RE GOING TO THE CONVENTION!

Our representative and exhibit at St. Louis will tell some of the reasons why more than 400,000 Mathews Hydrants are in use today, in every climate. In case of damage, the barrel, which contains all working parts, can be lifted out and a spare inserted. No pavement breaking, no digging, no dangerous interruption of service. The stuffing box, designed without bolts and nuts, is cast integral with the nozzle section. No water or dirt can get in, no rust can form. The revolving nut and stem thread are kept dry and frost-free.

For quick-changing the position of the outlet, the head rotates a full circle simply by loosening a few nuts. A low-placed orifice drains all the water, preventing freezing. The revolving nut is capped with a malleable iron shield that's resistant to wrench-wear and protects the nut against rain and snow. The valve opens *against* and closes *with* the pressure. Oiling is done from the *outside*. The protection case is "Sand-Spun" for greater strength, elasticity, freedom from stresses.

Is it any wonder that Mathews have led the world for three-quarters of a century?

MATHEWS HYDRANTS

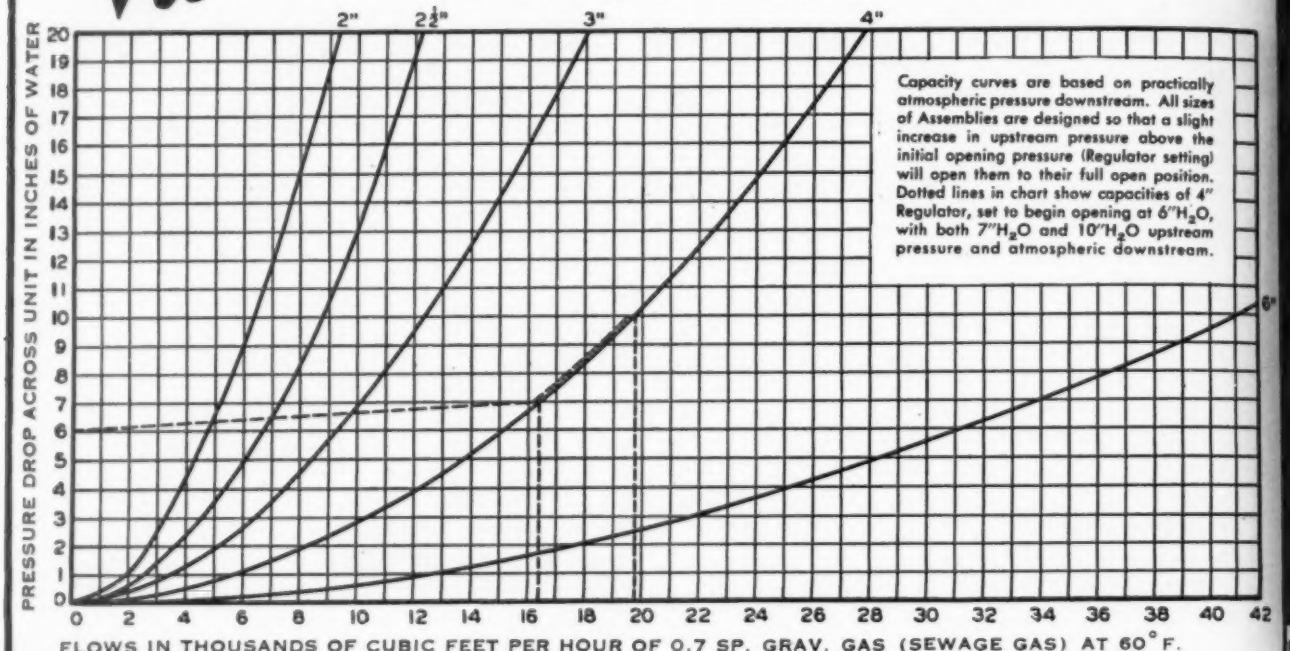
Made by **R. D. WOOD** *Company*

PUBLIC LEDGER BUILDING
INDEPENDENCE SQUARE, PHILADELPHIA 5, PA.

MANUFACTURERS OF SAND SPUN PIPE (CENTRIFUGALLY CAST IN SAND MOLDS) AND R. D. WOOD GATE VALVES

SAFE SEWAGE GAS CONTROL

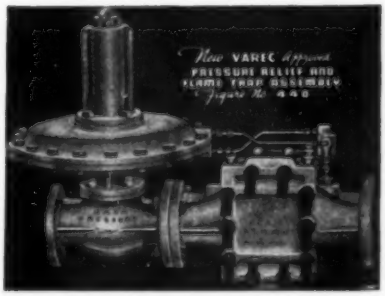
"Varec" PRESSURE RELIEF AND FLAME TRAP ASSEMBLY


2"
2½"
3"
4"
6"
PRESSURE DROP ACROSS UNIT IN INCHES OF WATER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
FLOWS IN THOUSANDS OF CUBIC FEET PER HOUR OF 0.7 SP. GRAV. GAS (SEWAGE GAS) AT 60° F.
Capacity curves are based on practically atmospheric pressure downstream. All sizes of Assemblies are designed so that a slight increase in upstream pressure above the initial opening pressure (Regulator setting) will open them to their full open position. Dotted lines in chart show capacities of 4" Regulator, set to begin opening at 6"H_2O, with both 7"H_2O and 10"H_2O upstream pressure and atmospheric downstream.

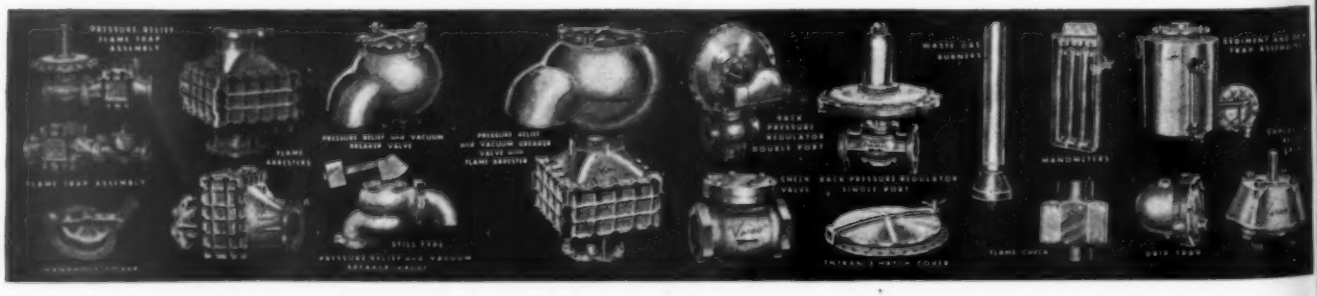
THE PACE SETTER SINCE 1928

"VAREC" offers a simple, fool-proof unit—sensitively positive operation—a positive flame trap. The fusible element melts at 200°F. and stops gas flow within 15 seconds. The element is so designed that shut-off valve cannot possibly close unless contacted by flame. The new "VAREC" Sewage Gas Control Handbook S-3 is packed with information, illustrations, flow diagrams, charts and data of value to sanitation engineers. Write for your copy today.

THE VAPOR RECOVERY SYSTEMS COMPANY
COMPTON, CALIFORNIA
NEW YORK CITY—CHICAGO, ILL.—HOUSTON, TEX.—TULSA, OKLA.
Agencies Everywhere—Cable Address VAREC-COMPTON (All Codes)



This Unit consists of a diaphragm-operated Regulator, Flame Trap and Thermal Shut-off Valve. It maintains a predetermined back pressure, passing surplus gas to the waste gas burner. It stops Flame Propogation. Patented extensible Flame Trap element simplifies inspection and maintnance. It is non-corrosive. Sizes 2" to 6".



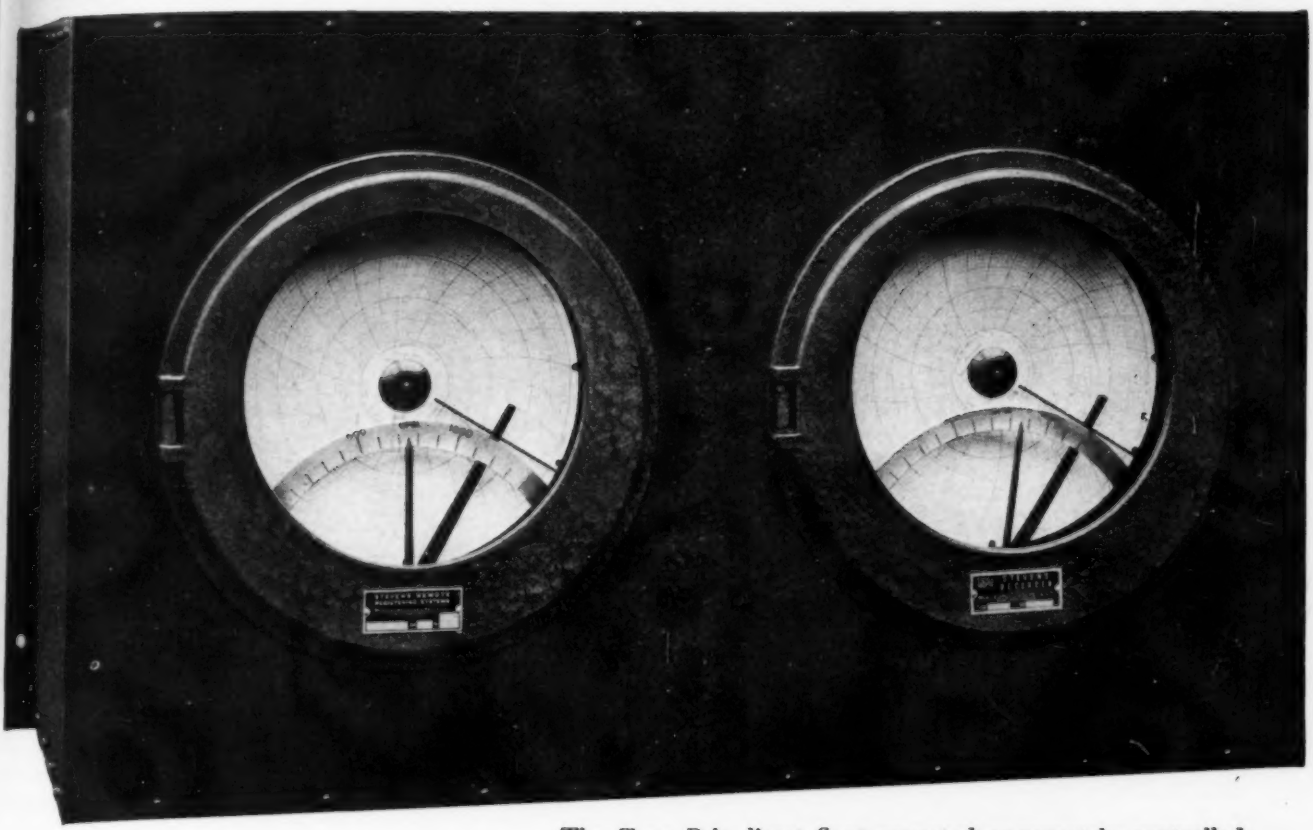
STEVENS TYPE B RECORDER DOES 3 JOBS WELL

The user list of Stevens *Type B* Recorder reads like a Blue Book. Reason — the instrument is particularly adapted to waterworks, sewerage and industrial applications — and is equally suitable to any class of recorder service.

Type B is really *triplets*. It records and indicates either head or rate of flow and registers total volume passed in any elapsed time.

Circular charts are used and may be had for daily or weekly operation.

✓RECORDS AND INDICATES HEAD OR FLOW ✓TOTALIZES FLOW



The *Type B* is direct float operated or remotely controlled. Quality 8 day or electric clock is standard equipment. The recorder can be mounted on wall, pedestal, panel, or in sewer manhole. It can be hermetically sealed against corrosive fumes.

Want more information about this 3-way wonder? Write for Bulletin 25.

LEUPOLD & STEVENS INSTRUMENTS

MANUFACTURERS SINCE 1907

PORTLAND 13, OREGON

Hydrographic, Surveying, Navigation, Automatic Controls

Leupold & Stevens Instruments
4445 N. E. Glisan St. Portland 13, Oregon
Please send Bulletin No. 25 on the Stevens *Type B* Recorder.

Name _____

Organization _____

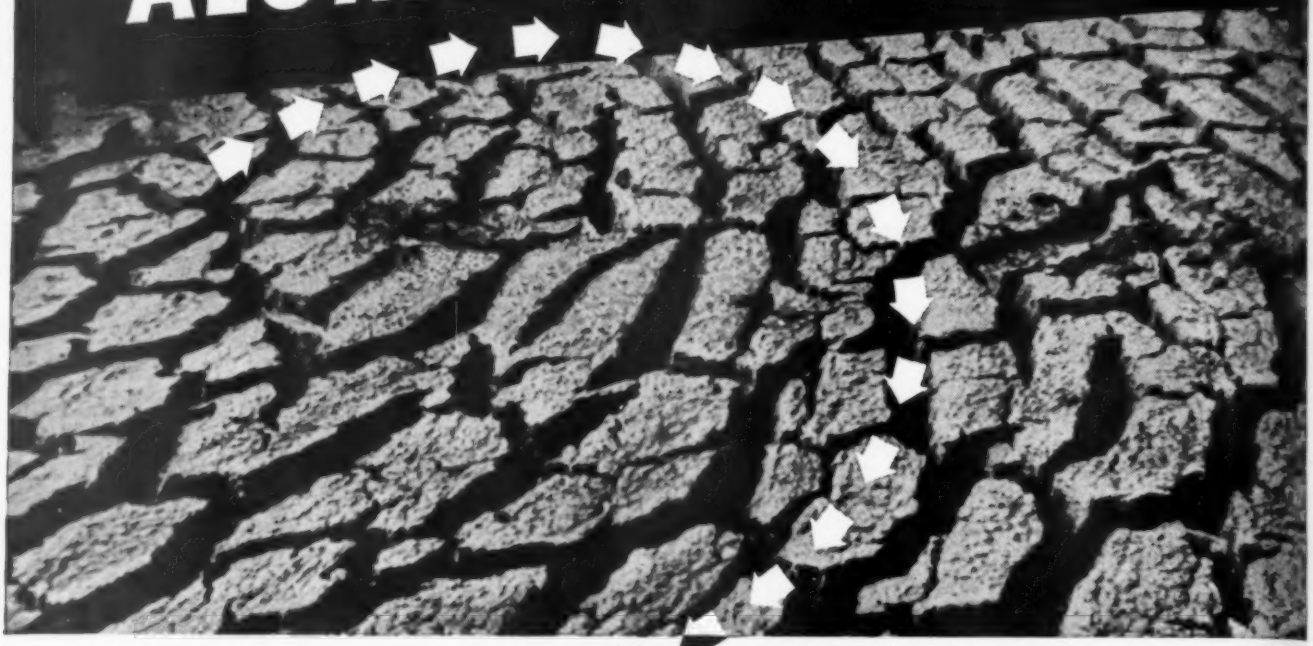
Title _____

Street _____

City _____ *Zone* _____ *State* _____

L&S

GENERAL CHEMICAL ALUMINUM SULFATE



Well cracked sludge bed shortly after Aluminum Sulfate treatment.

SPEEDS SLUDGE DRYING

General Chemical Alum speeds sludge dewatering and drying on sand beds... capacity of beds may be doubled, even tripled . . . quick removal lessens chance of odor nuisance . . . reduced volume of cake decreases cost of removal. Sewage works operators the nation over count on the benefits obtained from Alum treatment throughout the year.

Why not learn what General Chemical Alum will do in your plant too? Full information may be obtained quickly from the nearest General Chemical Sales and Technical Service Office listed below.

BASIC CHEMICALS

GENERAL CHEMICAL COMPANY

FOR AMERICAN INDUSTRY ©

GENERAL CHEMICAL COMPANY

40 RECTOR STREET, NEW YORK 6, N. Y.

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In Wisconsin: General Chemical Wisconsin Corporation, Milwaukee, Wis.

In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver

Engineered EQUIPMENT for WATER and SEWAGE PLANTS

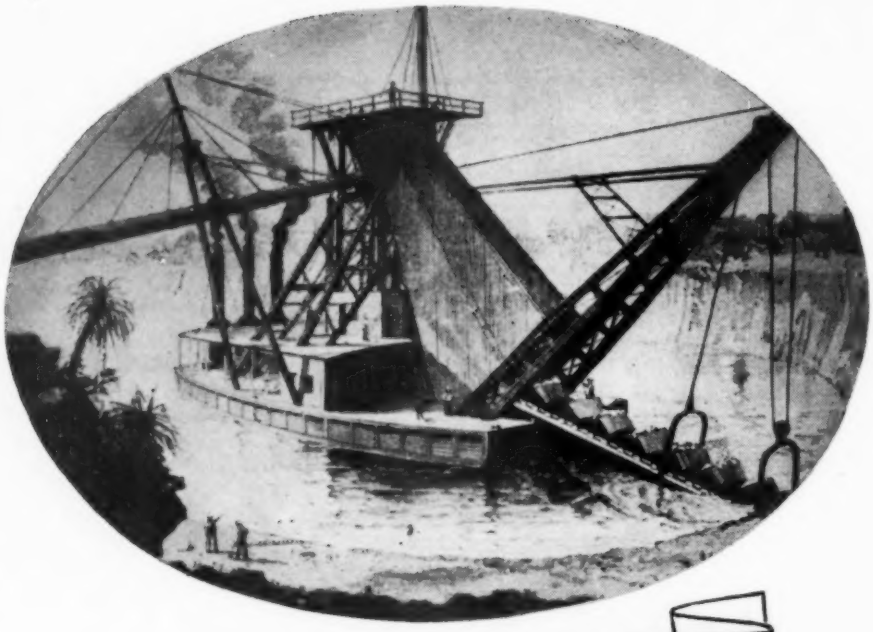
Over the years Simplex users have continued to show their preference for Simplex on *performance.*

Simplex Users STAY *Simplex Users . . .*

SIMPLEX Equipment for
Water and Sewage Treatment Plants

Meter Registers . . . Rate of Flow Controllers . . . Loss of Head and Rate of Flow Gauges . . . Elevation Gauges . . . Sand Expansion Indicators . . . Pilot Equipment . . . Air Release Valves . . . Air and Vacuum Valves . . . Venturi Tubes and Other Primary Devices . . . Hydraulic Equipment of Special Design . . .

SIMPLEX VALVE & METER COMPANY
6743 UPLAND STREET, PHILADELPHIA 42, PENNA.



Famous Facts

The Panama Canal, constructed with such huge dredges as the one illustrated, was officially opened to commerce in August, 1915. Interest in the project had been active since 1850, and its completion was a major engineering triumph.

Bitumastic Enamel — introduced in the early 1850's — had a long record of excellent performance as a protective coating, and was applied to the lock gates and penstocks of the Panama Canal in 1912-14. Inspected in 1925, enamel and steel showed no deterioration from the corrosive waters of Gatun Lake.

Today, Bitumastic Enamel, applied by the modern spun lining and coating process, has revolutionized the internal and external protection of cast iron and steel, water and sewer pipe. It affords positive protection against tuberculation with no appreciable reduction in flow capacity, and has an initial Williams and Hazen coefficient of 155 for 16-inch pipe or larger. It has a high viscosity, great flexibility, and is further characterized by tenacious adherence, and dependable protection under severe soil stress and corrosion conditions.

WAILES DOVE-HERMISTON

CORPORATION

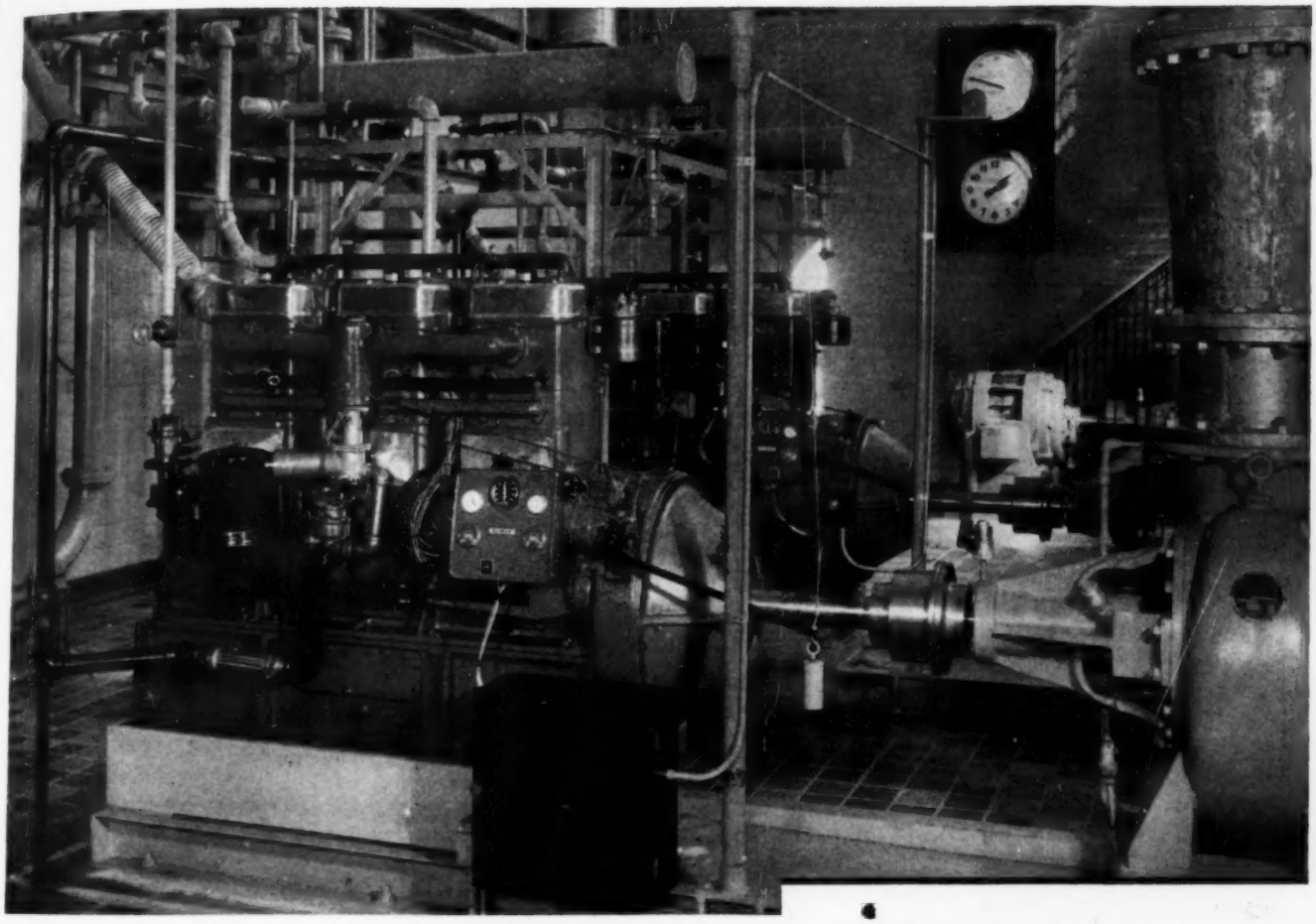
WESTFIELD, NEW JERSEY

New York 4 • Philadelphia 8 • Cleveland 14 • Chicago 3 • Houston 2 • Tulsa 3 • Miami 36
San Francisco 10 • Los Angeles 1

CHEAP POWER

¼¢ PER KILOWATT HOUR

with Climax Engines utilizing COSTLESS FUEL*

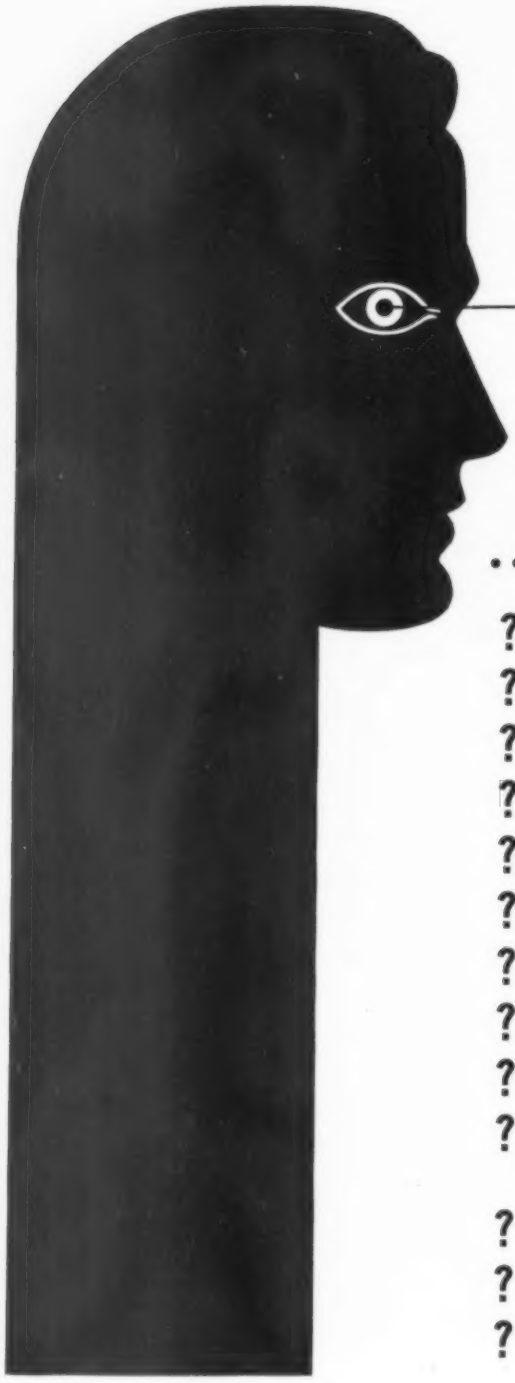


Two 75 H.P. Climax Sewage Gas Engines Direct Connected to Sewage Pumps, Kenosha, Wisconsin.

*Climax Engines, operating smoothly and efficiently on sewage gas, generate power for the equivalent of ¼ cent or less per kilowatt hour. For a plant serving a population of 20,000 or more, this ¼ cent cost rate would include *all costs* —maintenance, lubricating oil, interest on investment and depreciation. In addition to this saving, 50% heat recovery from jacket water and exhaust may be used to heat digester tanks and buildings.

Consider Climax Engines before approving a new installation. There are 4, 6, 8, and 12 cylinder, 4-cycle types that operate economically on gasoline, butane, sewage or natural gas. For complete information and specification bulletins, write Climax Engineering Company, Clinton, Iowa.

climax
BLUE STREAK ENGINE
Builder of Climax DIESELS and GENERATING SETS
CLIMAX ENGINEERING COMPANY



do you know?

...That Waterworks NO-OX-ID No. 6

? does not become brittle with age?
? does not require a primer for application?
? imparts no taste or odor to water?
? contains proven rust inhibitors?
? has exceptionally high C factor?
? has high dielectric strength?
? is tough and flexible, never hard or brittle?
? gives off no objectionable fumes in application?
? excels in low water absorption?
? only requires a thickness of 1/32 inch for lining or coating for complete protection?
? does not cold flow?
? loses no volume by volatilization?
? maintains its bond?

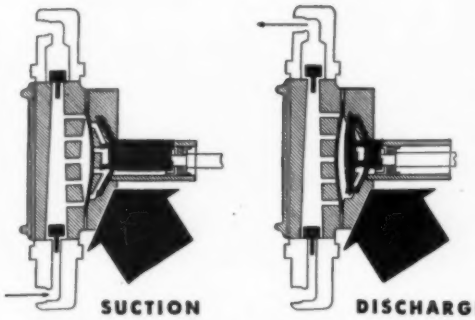
A high I.Q. in this test calls for a demonstration. Feel free to ask us to come to your office for that purpose.

NO-OX-ID IRON RUST
REG. TRADEMARK AUG. 27, 1918

The ORIGINAL RUST PREVENTIVE

Dearborn Chemical Company
Dept. Y, 310 S. Michigan Ave., Chicago 4, Ill.
New York • Los Angeles • Toronto

THE *Diaphragm* DOES IT!



The Wilson Pulsafeeder operates on the positive displacement principle of the horizontal reciprocating pump. The exclusive Pulsafeeder feature, however, is an hydraulically-balanced diaphragm which isolates the piston and cylinder from the chemical solution being pumped. No contamination of water supply by the pump; no corrosive attack on pump parts by chemical solutions.

★ **ISOLATES CHEMICAL SOLUTION FROM OPERATING PARTS**

★ **NO PACKING GLANDS**

★ **BALANCED HYDRAULIC PRESSURE**

★ **POSITIVE DISPLACEMENT PISTON PRINCIPLE**

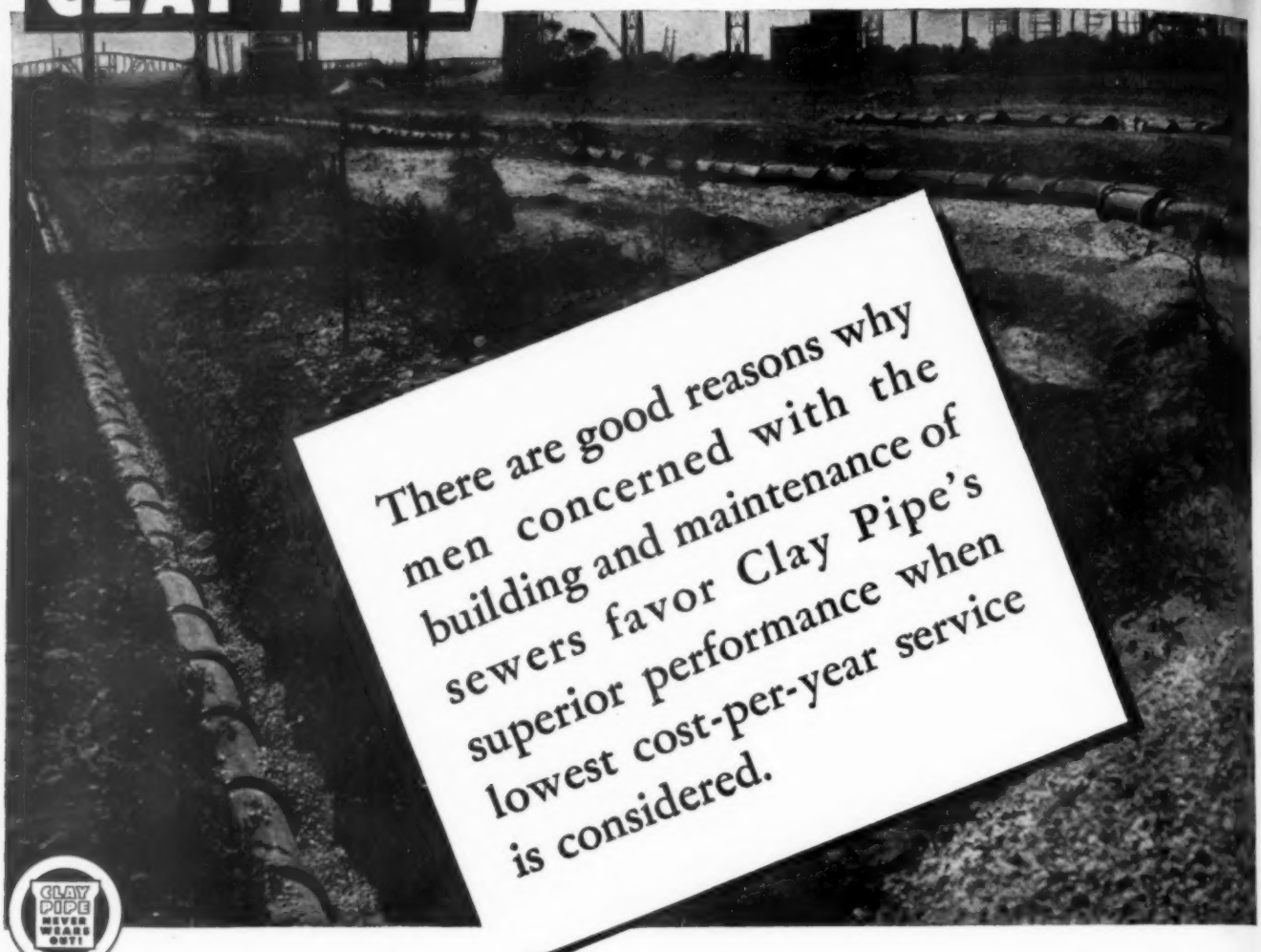
Wilson
PULSAFEEDER

PATENTS APPLIED FOR

Long life of chemical feeding equipment and protected purity of your water supply is assured by the Wilson Pulsafeeder, the *balanced-diaphragm* Hypochlorinator and chemical feeder. Its rate of flow is continuously adjustable *while in operation.* Meter-controlled model maintains exactly proportioned feeding regardless of rate of water consumption. Sealed lubrication—all moving parts, except the motor, running in oil. Write for new illustrated description and specifications. *Process Equipment Division, Lapp Insulator Co., Inc., 117 Maple St., LeRoy, N. Y.*

Lapp

Specify CLAY PIPE TO GET THE LOWEST Cost-Per-Year SEWERAGE


There are good reasons why men concerned with the building and maintenance of sewers favor Clay Pipe's superior performance when lowest cost-per-year service is considered.
CLAY PIPE NEVER WEARS OUT!

Clay Pipe does the job right, and lasts longer than any other material . . . because it never wears out. Enduring clay, shaped under great pressure and vitrified at fusing temperatures, produces the hard, strong, finished pipe that has no equal. Properly installed Clay Pipe does not require periodic or frequent replacement. Because it is chemically inert, it defeats corrosion, crumbling and rust problems that make other sewers short-lived.

And for extra-heavy live or static loads where vehicles roll, where the back-fill is unusual or the trench shallow, where it is desirable to eliminate or reduce cradling or casement costs . . . Extra-Strength Clay Pipe does an outstanding job.

For information or engineering literature from one of the regional association offices, write to:

National Clay Pipe Manufacturers, Inc.
111 W. Washington St., Chicago 2, Ill.

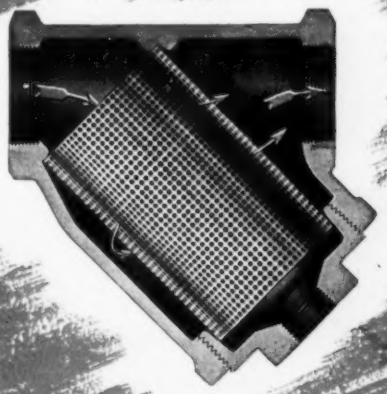
NOW!...POSITIVE PROTECTION from Abrasives

for Instruments, Regulators, Pumps, Traps, Meters, etc.

Installed ahead of regulators, pumps, traps, etc., McAlear No. M-530 Strainer positively removes all grit, pipe cuttings and other abrasive materials from pipe lines. It is instantly cleaned by opening of blow-off in flange.

BODY is precision-machined cast iron with screwed ends. Monel metal 20-mesh (400 holes per square inch) is standard. 40-mesh (1600 holes per square inch) available on special order. Working pressures up to 125 p.s.i. Sizes ½" to 2" available for *immediate* delivery.

For informative bulletin, write McAlear Manufacturing Company, Automatic Control Division of Climax Industries, 1949 S. Western Avenue, Chicago 8, Illinois.



McALEAR No. M-530
New High Quality, Low-Cost, Self Cleaning Y-Type Strainer—with Monel Metal Basket

EXTRA SENSITIVE, accurate, easily adjusted new McAlear No. M-3101 (self-powered) Temperature Regulator for steam, water or gas.

Precision

TEMPERATURE CONTROL AT LOW COST

★ *FOR PROCESS INDUSTRIES*
★ *FOR HEATING APPLICATIONS*

STANDARD temperature range: 140° to 180° F. Sizes: ½ to 2 inches. Construction: Union ends, double port, bronze body, bulb and fittings standard. Spiral wound, brass armored tubing standard length 8 feet. Other sizes available in ranges of 40° each from 70° to 260° F.

This new McAlear No. M-3101 incorporates all the advanced features developed by McAlear in 35 years of building temperature controls for heating and processing.

Trim, compact and rugged, it establishes new standards of sensitivity, dependable accuracy and easy adjustment. Write for bulletin.

CLIMAX INDUSTRIES

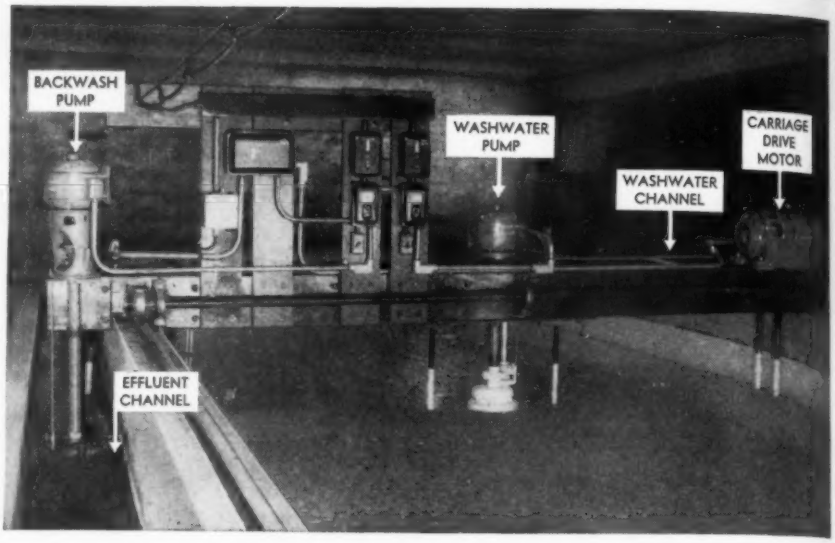
McALEAR
PRESSURE · FLOW · LIQUID LEVEL · TEMPERATURE
controls
for STEAM, WATER, AIR, OIL—GAS

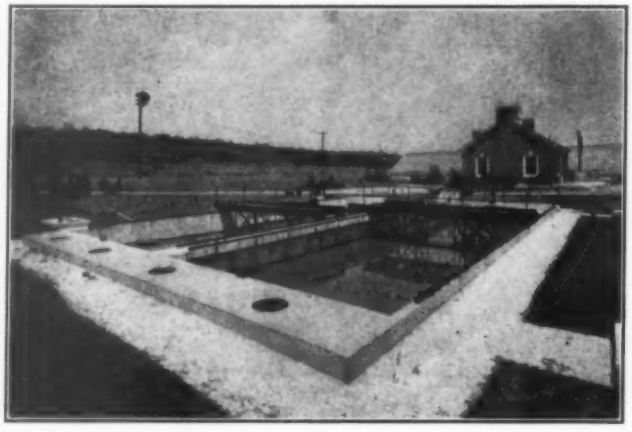
POLLUTION REMOVAL EQUIPMENT BY THE HARDINGE COMPANY

37 YEARS OF SERVICE TO INDUSTRY

Automatic Backwash Rapid Sand Filter •

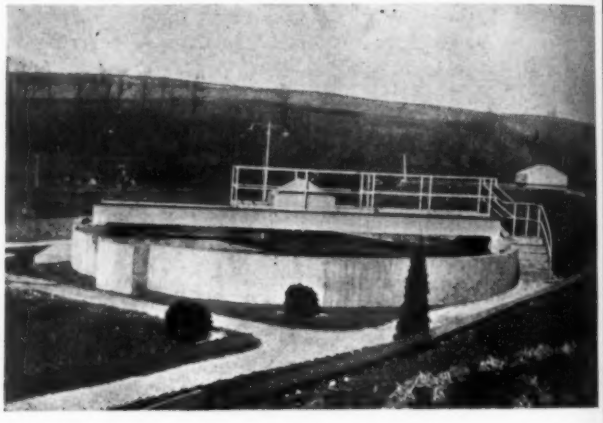
This effluent filter is particularly valuable where high removal of suspended solids is desirable, but where high removal of B.O.D. may not be necessary. In such cases, following the primary clarifier, it provides 75%-80% removal of suspended solids; 90% or better if chemicals are added. Also efficient in producing final effluent of high clarity from settling tanks in trickling filter and activated sludge plants.





Rectangular Tank Clarifier •

Consists of a bridge crane which spans width of the tank and supports the sludge scraper and skimmer. It moves automatically back and forth along the tank, moving all settled solids into sludge hoppers at one end.



Circular Tank Clarifier •

The rotating sludge scraper is supported and operated from two beams which span the tank top. Clarifier driving mechanism is entirely enclosed in waterproof drive housing which is neat in appearance, yet rugged.

OTHER HARDINGE EQUIPMENT

for sewage treatment, water treatment, and industrial wastes—such as Hardinge Digesters—are described in the following bulletins: 30-A, 31-D, 35-B. *Request these bulletins by number for complete data on Hardinge equipment in these three fields.*

CONSULT NEAREST OFFICE

HARDINGE COMPANY, INCORPORATED • YORK, PENN.

NEW YORK 17—122 E. 42nd St. • 205 W. Wacker Drive—CHICAGO 6

SAN FRANCISCO 5—501 Howard St. • 200 Bay St.—TORONTO 1

Welcome!

We join with our customers in welcoming the return of many of their employees from military and other national service to the positions they held in offices and plants.

We share the natural pride your employers take in your service to the nation and the hopes they have for your future.

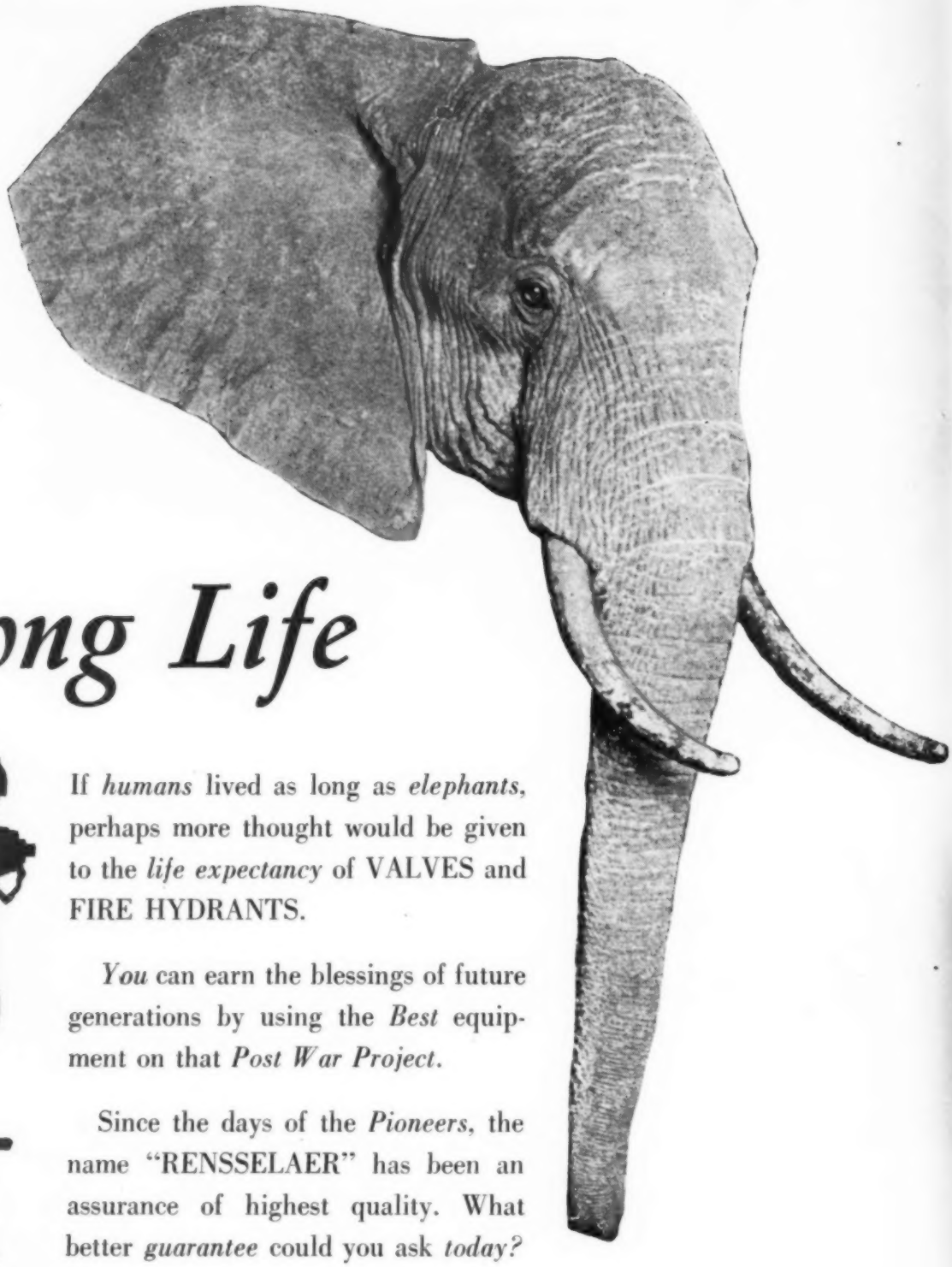
Our representatives have already had the pleasure of personally greeting many of you who have served . . . they look forward to renewing their associations with all of you.

COLUMBIA ESSENTIAL INDUSTRIAL CHEMICALS

Soda Ash • Caustic Soda • Liquid Chlorine • Sodium Bicarbonate • Pittchlor (Calcium Hypochlorite) • Silene EF (Hydrated Calcium Silicate) • Calcium Chloride • Soda Briquettes • Caustic Ash • Phosflake • Calcene T (Precipitated Calcium Carbonate) • Modified Sodas.

COLUMBIA CHEMICALS

PITTSBURGH PLATE GLASS COMPANY
COLUMBIA CHEMICAL DIVISION
FIFTH AVENUE at BELLEFIELD • PITTSBURGH 13, PA.
CHICAGO • BOSTON • ST. LOUIS • PITTSBURGH • NEW YORK • CINCINNATI • CLEVELAND
PHILADELPHIA • MINNEAPOLIS • CHARLOTTE • SAN FRANCISCO



Long Life

If *humans* lived as long as *elephants*, perhaps more thought would be given to the *life expectancy* of VALVES and FIRE HYDRANTS.

You can earn the blessings of future generations by using the *Best* equipment on that *Post War Project.*

Since the days of the *Pioneers*, the name "RENSSELAER" has been an assurance of highest quality. What better *guarantee* could you ask *today?*

"I have always insisted that *quality* is of first importance."

(Quotation from the letters of Mr. E. Rowe, Founder of the Rensselaer Valve Co.)

"Ask the man who uses **RENSSELAER"**

RENSSELAER VALVE CO., TROY, N. Y.

Days and Dollars

CAN BE SAVED IN THE LAYING OF BELL and SPIGOT WATER MAIN

Using *Tegul*-MINERALEAD for jointing, it isn't necessary to let trenches stand open for days or weeks waiting for joints to seal and leaks to stop. Thiokol, the plasticizer in *Tegul*-MINERALEAD, reduces initial leakage. Trenches can be back-filled almost as soon as joints are poured. Traffic hazards due to open trenches are minimized. Premises can be tidied up quickly.

Tegul-MINERALEAD saves in both laying and maintenance. Its 10 lb. ingots are convenient to handle, store and ship. Physical composition cannot be upset under jolting en route to you. *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our plant.

Sudden storms or floods which might spoil some compounds if left unprotected, have no effect upon *Tegul*-MINERALEAD solid ingots. Even drying out is unnecessary.

Tegul-MINERALEAD joints have much higher resistance to mechanical and thermal shock — not to be overlooked where nearby heavy traffic or heavy plant machinery operates — or water at high temperatures is to be carried.

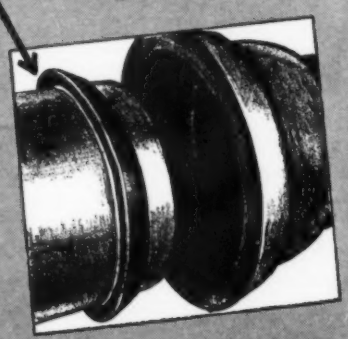
An ATLAS representative can be reached at the nearest office listed. For illustrated technical literature, write our Mertztown Office.

The HYDE-RO Ring

ANOTHER ATLAS AID TO BETTER BELL AND SPIGOT LINE JOINTING

Cuts water waste. Saves repeated hypochlorite flushings. Speeds repairs by giving dry joints. Works with Tegul-MINERALEAD, lead and Portland Cement.

•Serves on Beaded end pipe and Straight end pipe. . . . Write for literature.



THE Atlas Mineral

PRODUCTS COMPANY OF PENNA.

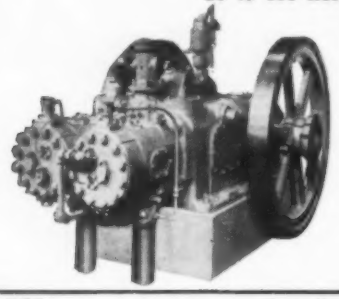
MERTZTOWN PENNSYLVANIA	
*ATLANTA 3, Ga., 161 Spring St., N. W.	*KANSAS CITY 2, Kan., 1913 Tauromee Ave.
*CHICAGO 1, Ill., 333 No. Michigan Ave	NEW YORK 16, N. Y., 280 Madison Ave.
*DALLAS 5, Tex., 3921 Purdue St.	PITTSBURGH 10, Pa., 4656 Old Boston Rd.
*DETROIT 2, Mich., 2970 W Grand Blvd	ST LOUIS 8, Mo., 4485 Olive St.

THE ATLAS MINERAL PRODUCTS COMPANY OF CALIFORNIA, Redwood City, California

*DENVER 2, Colo., 1921 Blake St	SAN FRANCISCO 7, Calif., Rensselaer Valve Co., 115 Townsend St.
*HONOLULU 2, Hawaii, U. S. A	*SEATTLE 4, Wash., Rensselaer Valve Co., 1252 First Avenue, S.
*LOS ANGELES 12, Calif., 817 Yale St.	*Stocks carried at these points.
*SALT LAKE CITY 11, Utah, 1212 So. State St	

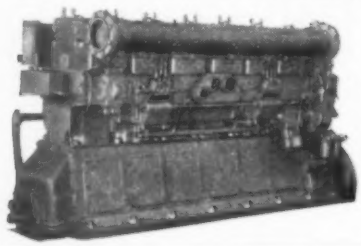
IN CANADA: Atlas Products are manufactured by H. L. BLACHFORD, LTD., 977 Aqueduct Street, Montreal, P. Q.

TYPE GA ..... 1 or 2 cylinders
25 to 110 horsepower

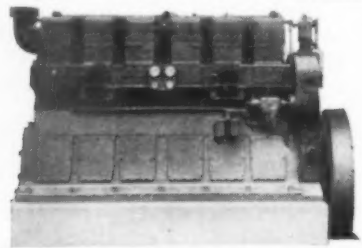


TYPE EN ..... 6 or 8 cylinders
Atmospheric ..... 135 to 400 horsepower
Supercharged ..... 185 to 550 horsepower

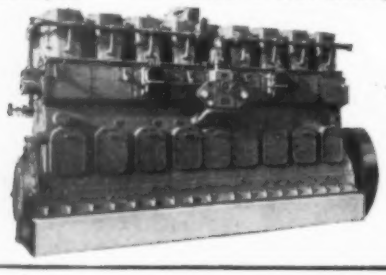
TYPE GS ..... 5, 6, 7, or 8 cylinders
Atmospheric ..... 290 to 750 horsepower
Supercharged ..... 310 to 1000 horsepower



TYPE JS ..... 6, 7, or 8 cylinders
Atmospheric ..... 410 to 930 horsepower
Supercharged ..... 550 to 1260 horsepower



TYPE LS ..... 6, 7, or 8 cylinders
Atmospheric ..... 650 to 1280 horsepower
Supercharged ..... 880 to 1730 horsepower



Cooper-Bessemer DIESELS

★ Reliable ★ Efficient ★ Enduring

If your power requirements fall between 25 to 1800 horsepower, there is an efficient, long-lived Cooper-Bessemer engine exactly suited to your needs. Cooper-Bessemer diesel generating sets and direct-drive engines are widely used throughout industrial America wherever low-cost power, simplified operation, and trouble-free performance under continuance service are essential.

A few of the Cooper-Bessemer engines are shown here. All the vertical diesel and gas-diesel engines are available supercharged which affords up to 50 percent increased horsepower without increasing engine space requirements.

Particularly significant in industrial applications, Cooper-Bessemer gas-diesels can be furnished to operate with equal efficiency on either gas or customary oil fuels, or on virtually any combination of both at will. They may be changed instantaneously from one fuel to the other at full load without even reducing speed.

This revolutionary Cooper-Bessemer development permits remarkable fuel economies. Gas fuel can often be supplied at sharply reduced cost throughout the long off-peak season.

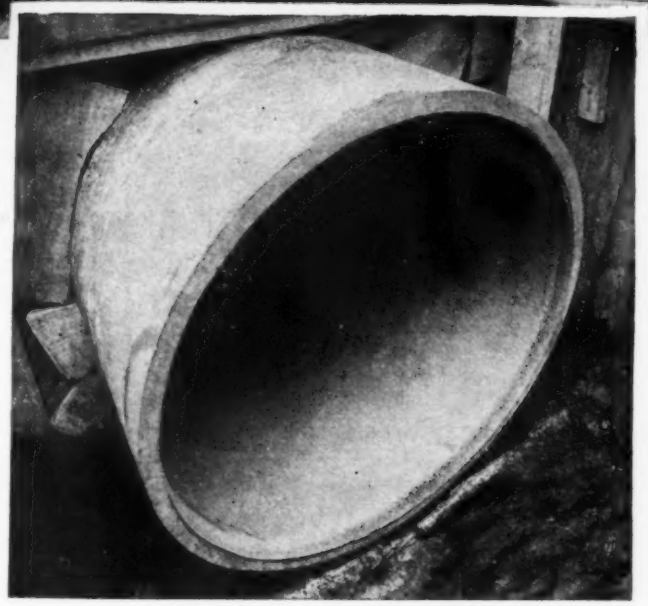
If you are interested in reduced operating costs and year after year of dependable, uninterrupted power service, contact the nearest Cooper-Bessemer office for bulletins and complete details on the proper power set-up for your needs.

THE COOPER-BESSEMER CORPORATION

Mount Vernon, Ohio — PLANTS — Grove City, Penna.

25 W. 43rd St., New York, N. Y. — Investment Building, Washington, D. C. — 1701-05 Arcade Building, St. Louis Mo.
1814 Mercantile Bank Building, Dallas, Texas — 529 M & M Building, Houston, Texas — 631 Spring St., Shreveport, La.
201 E. First Street, Tulsa, Oklahoma — 640 East 61st Street, Los Angeles, Calif. — 570 First Avenue, S., Seattle, Washington

CENTRILINE GOES TO WASHINGTON ...for the third time!



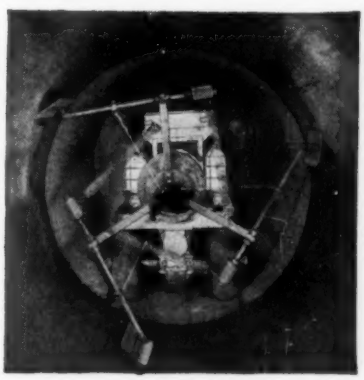
ONCE again Centriline was elected to service the nation's capital—and do another important reconditioning job for the Water Department of the District of Columbia. Nearly 30,000 feet of cast-iron pipe, varying in sizes from 30″ to 48″, were cleaned and cement lined—speedily and economically. This sleek new lining will provide a non-corrosive, non-tuberculating surface to shield the underlying metal—assuring a permanently high coefficient and increased longevity.

CENTRILINE CORPORATION

148 CEDAR STREET • NEW YORK 6, N. Y.

Restores and Protects Pipe-Line Carrying Capacity

The Centriline process is a rapid and economical method of reconditioning pipe lines of 30″ and larger. It consists of first cleaning the main, then applying by centrifugal force a dense cement mortar lining of required thickness, mechanically troweled to a smooth finish. This is done underground, in place.



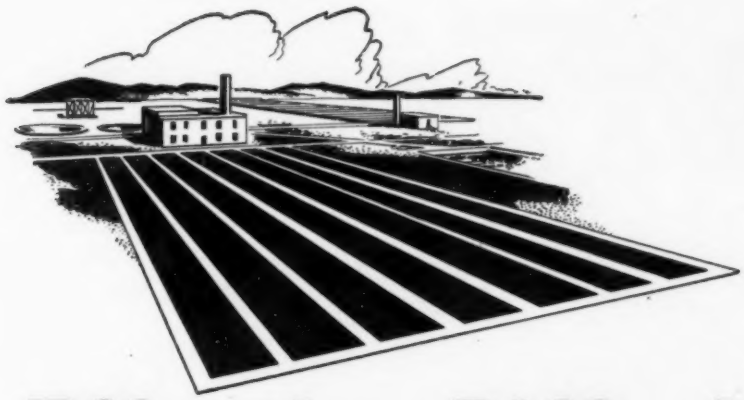
Original Woodcut by Lynd Ward

Centuries of service have established the long life and low maintenance cost characteristics of cast iron pipe. The science and art of making pipe has progressed steadily over these hundreds of years. We would welcome those who specify, buy, or use cast iron pipe, who wish to visit our plants and research laboratory to witness our current manufacturing process and controls. These modern methods result in a finer, more uniform pipe, either pit cast or centrifugally cast.

U.S. cast iron PIPE

U. S. PIPE & FOUNDRY CO.
General Offices: Burlington, N. J.

Plants and Sales Offices throughout the U. S. A.



Getting Effective Diffusion In Activated Sludge Treatment

The most practical and economical modern method of complete sewage treatment is generally recognized as being Activated Sludge Treatment by air diffusion. Its many advantages in accomplishing satisfactory results under the most critical conditions are well known to sanitary engineers.

In selecting the correct diffusers for optimum results, careful consideration of many factors is necessary. Characteristics of tanks, blowers, and piping as well as the size, shape, permeability and arrangement of diffusers are only a few. More important, the nature of these factors varies for each individual design application.

This specialized character of diffuser application has long been recognized by The Carborundum Company. To help solve the many problems it presents, we have put together a practical organization of experienced engineers.

These engineers are available to consult with design consultants, superintendents, contractors and others. These men are familiar with the field of sewage and sanitation. Their knowledge is gained from dealing daily with the peculiar problems presented. Their experience covers a wide variety of diffuser applications. They welcome the opportunity for discussion.

Give us the opportunity to show how this combination of knowledge and experience can prove a practical help in getting most effective diffusion. There is no obligation, of course. Write Dept. O-46, The Carborundum Company, Refractories Division, Perth Amboy, New Jersey.

DIFFUSER MEDIA

BY CARBORUNDUM

TRADE MARK

"Carborundum" is a registered trademark which indicates manufacture by The Carborundum Company

LOOK AT THE LENGTH...

...it's the key to an important Transite economy

THAT LONG 13-foot section of Transite Sewer Pipe you see in the photograph is one reason why handling costs are lower with this modern asbestos-cement pipe. Long lengths mean fewer joints to assemble—and, together with Transite's light weight, fewer man-hours to lay this pipe to line and grade.

Lower handling costs are one of several far-reaching economies possible with Transite Sewer Pipe. Others include:

Lower excavation costs. Because of its low friction coefficient (n = .010), Transite Sewer Pipe has an unusually high flow capacity. Thus, flatter grades, with correspondingly lower excavation costs, are often permitted.

Use of smaller pipe. Instead of using flatter grades, designers sometimes take advantage of Transite's high flow capacity to use smaller diameter pipe.

Reduced treatment costs. Transite Sewer Pipe joints combine tightness with flexibility and so guard against infiltration. Fewer, tighter joints reduce load at disposal plant, help keep treatment costs low.

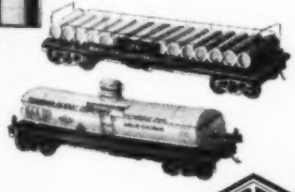
Smaller treatment plants. Possible because Transite minimizes infiltration. Where new plants are being designed, substantial savings in the initial cost of construction and equipment may be effected.

More details on Transite Sewer Pipe for gravity lines are given in brochure TR 21-A; on Transite Pressure Pipe for force mains and water lines, in brochure TR 11-A. For copies, write Johns-Manville, Box 290, New York 16, N. Y.

Johns-Manville

TRANSITE SEWER PIPE *for gravity lines* — **TRANSITE PRESSURE PIPE** *for force mains*

Protection Plus



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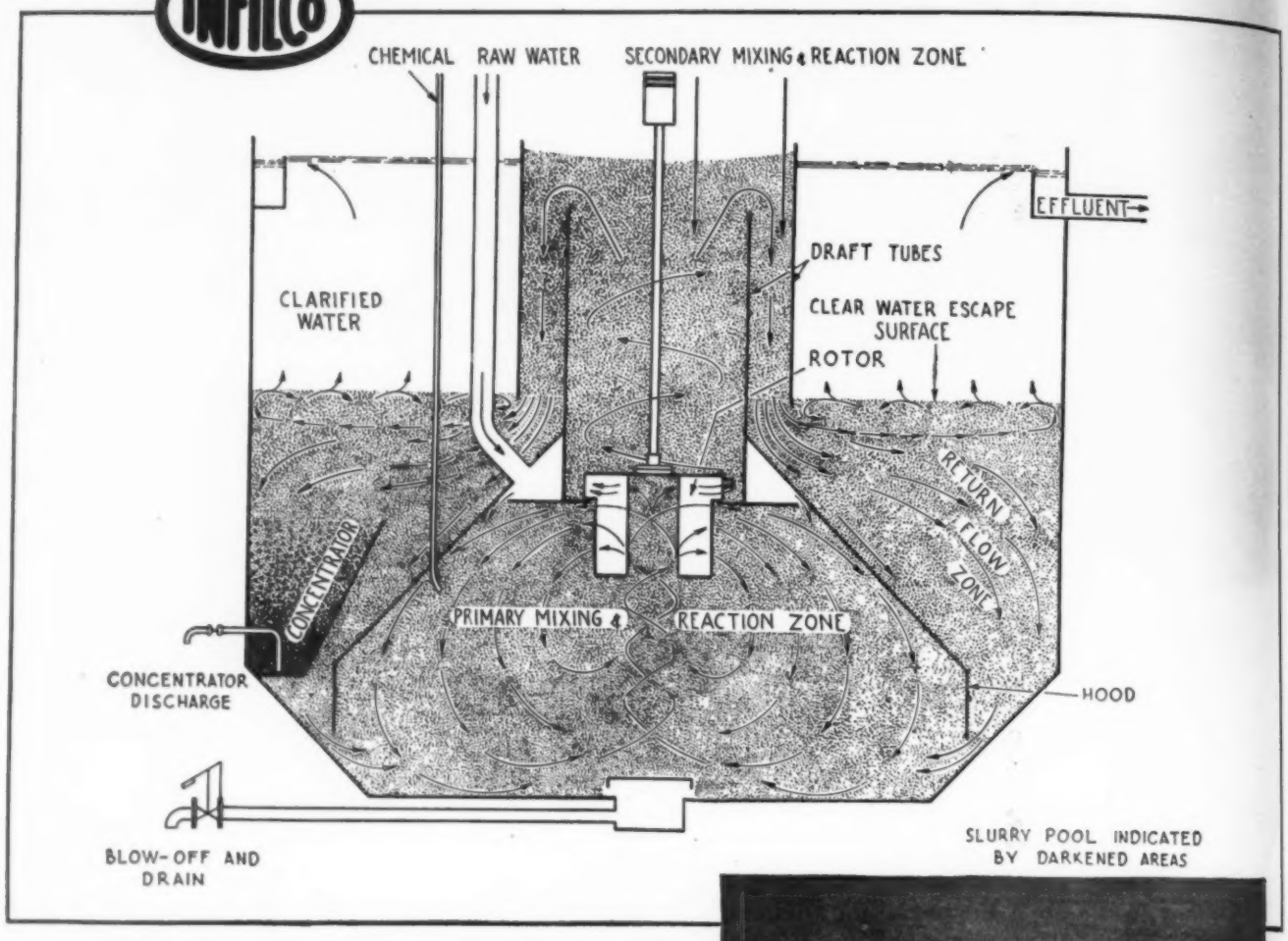

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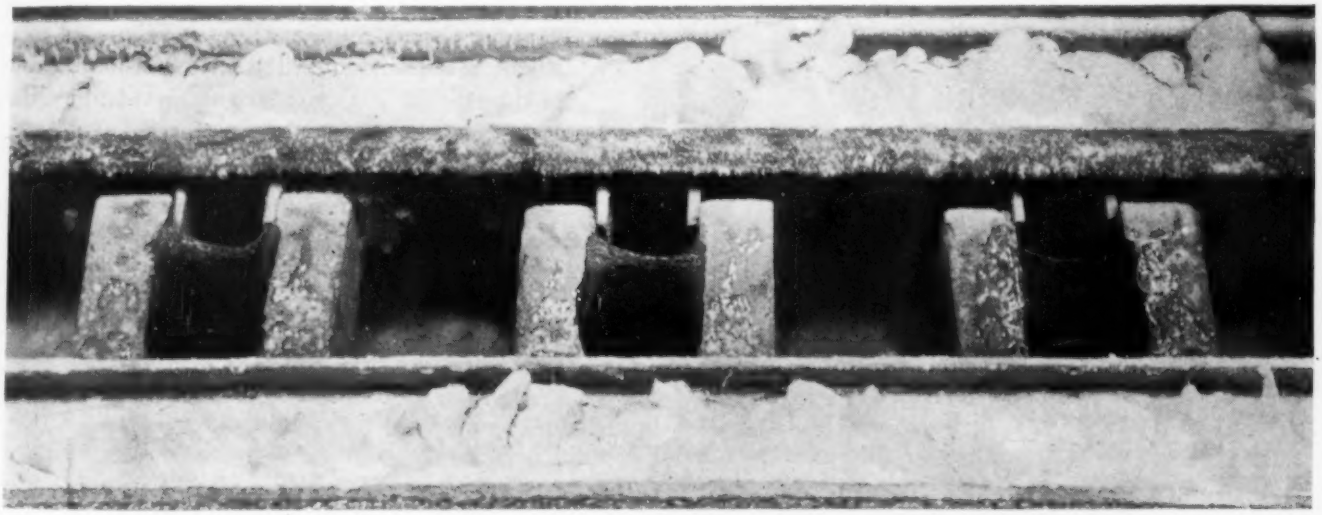

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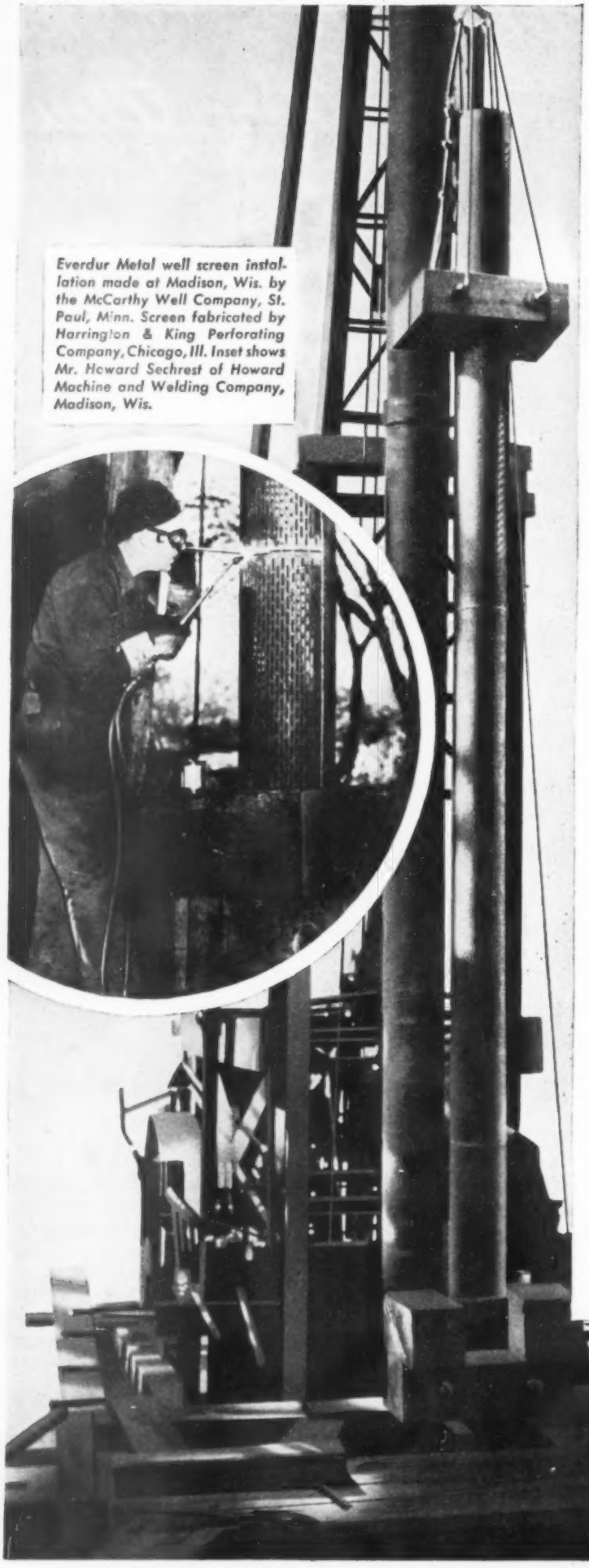

Everdur Metal well screen installation made at Madison, Wis. by the McCarthy Well Company, St. Paul, Minn. Screen fabricated by Harrington & King Perforating Company, Chicago, Ill. Inset shows Mr. Howard Sechrest of Howard Machine and Welding Company, Madison, Wis.

270-Ft. EVERDUR Screen puts new life into Old Well . . .

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For detailed information write for Publications E-11 and E-6.

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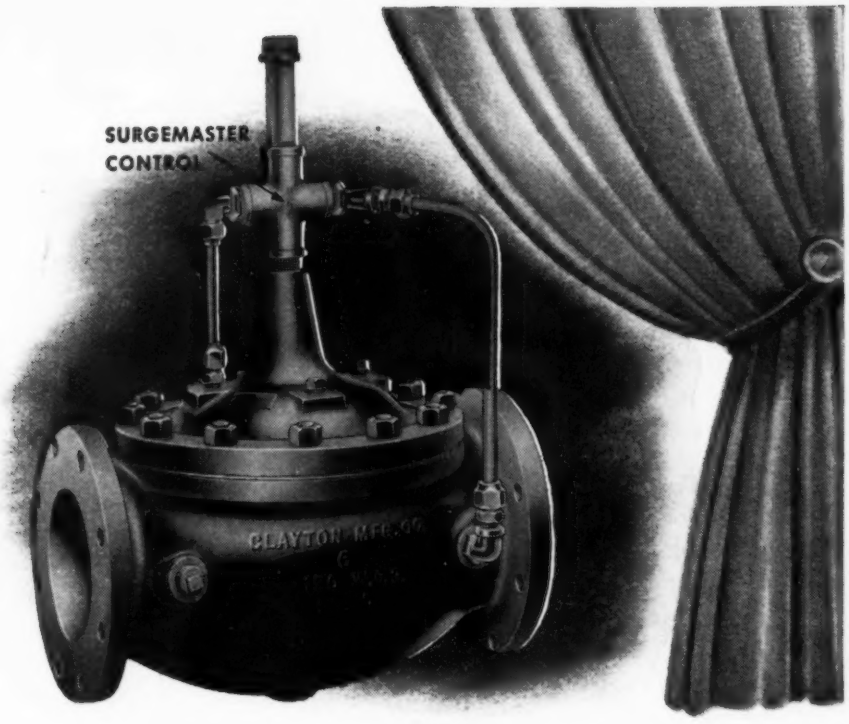

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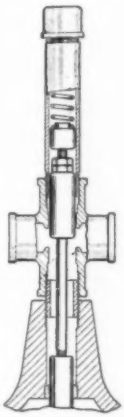

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WATER & SEWAGE WORKS

L. H. ENSLOW, Editor
155 East 44th Street, New York 17, N. Y.

E. S. GILLETTE, Publisher
330 South Wells Street, Chicago 6, Ill.

Water!

Our cover picture this month has no connection with any article in the issue. It was chosen, not alone for its sheer beauty, but also because this impressive picture was made on one of Oregon's snow-fed watersheds serving Salem and Albany in the Willamette Valley.

For this magnificent picture we are indebted to Ray C. Hansen, Sales Manager, National Tank & Pipe Co., Portland, Ore.

COMING!

"Installing and Maintaining Services and Meters"
Reveals practices in the installation and maintenance of service lines and meters which are employed by Winnipeg, Canada. Those who know the author, or are familiar with papers published by him, will need no further encouragement to be on the look-out for his article in our May issue. The author, believed to be Canada's youngest City Engineer, is—
WM. D. HURST,
City Engineer of Winnipeg, Canada.

"Telemarking"
Is an article describing the valuable installment of the "Telemark" and its dependability and uncanny accuracy in long-distance transmission of important water elevations at Miami, Fla., over a simple telephone circuit actuated by a single 15 volt dry cell battery. As the author points out, this system also has other applications of interest to water and sewage works operators. The contributor is—
C. F. WERTZ, Resident Engineer,
Dept. of Water and Sewers, Miami, Fla.

"Control of Sludge Bulking"
Is an article of interest to all operators of activated sludge plants—especially at this time of the approaching season of sludge bulking. This article, like another of recent publication date, has to do with the judicious and effective adaptation of return sludge chlorination as the corrective for bulky sludge conditions and loss of solids over the effluent weirs. So simple and efficacious has been this method that we consider it expedient to publish this helpful account requested of—
J. KENNETH ADAMS,
Supt. of Sewerage, Tenefly, N. J.

"Mathematics For Water and Sewage Works Operators"
Will be presented in several parts beginning with our May issue. This series of articles discusses the fundamentals of mathematical operations required in the management and operation of water and sewage works, and includes sections on fractions, decimals, percentage, proportion, physical units, rates, significant figures, graphs, logarithms, solutions, elementary hydraulics, and averages. This basic series of articles on mathematics, with examples of applications, is written by an experienced teacher of water and sewage works short schools—
DR. WARREN EGLOF,
Prof. Chem. of Eng., Niagara Univ., N. Y.

"The Control of Odors and Filter Fly Breeding"
Is a recounting of the most effective methods and procedures for the control of odors from trickling filters and the control of the filter fly nuisance at sewage treatment plants. Up to date, this article describes the effective use of the well known "D.D.T." in the eradication of the filter fly. The author is—
A. A. HIRSCH
State Dept. of Education, Baton Rouge, La.

"A New Concept of Coagulation"
Has been developed from considerations of gel formation and syneresis. Called the "protogel" theory, its application to the mechanism of coagulation and floc formation is compared to the current agglomeration theory by its proponent—
HAROLD R. HAY, Chemical Engineer,
Philadelphia Quartz Co., Phila., Pa.

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330 South Wells Street, Chicago 6, Ill.

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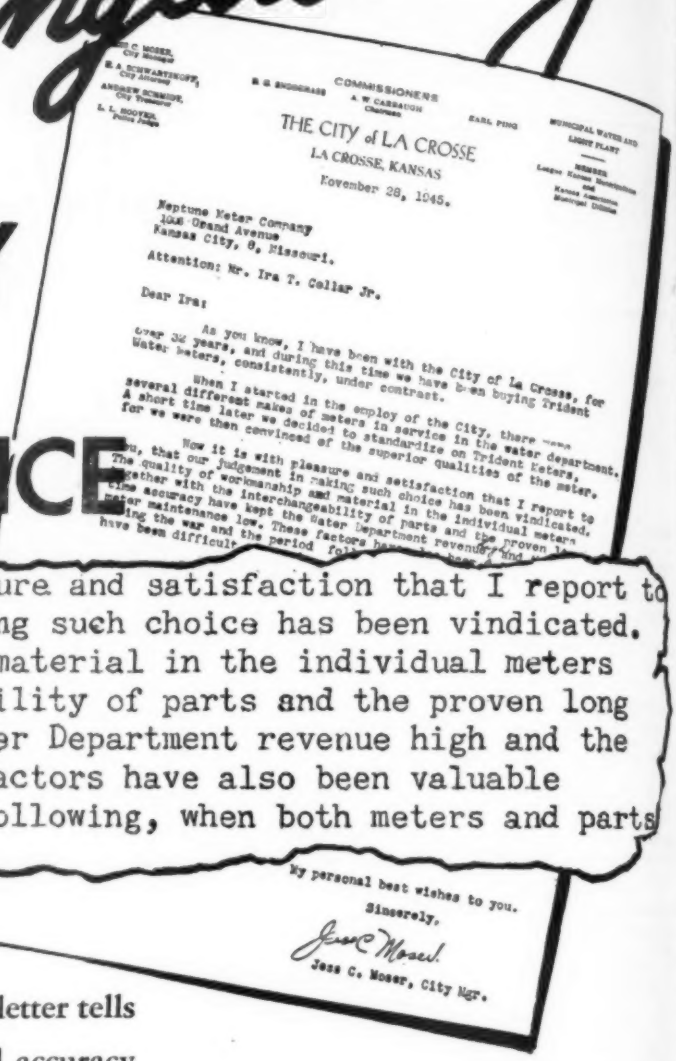

THE CITY of LA CROSSE
LA CROSSE, KANSAS

November 28, 1945.

Neptune Meter Company
1024 Grand Avenue
Kansas City, 6, Missouri.

Attention: Mr. Ira T. Collar Jr.

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Sincerely,

Jess C. Moser

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139

Over 6 million made and sold... the greatest majority still in service

To My Mother

Marie Harrison Enslow
1868--1946

TO my Mother do I dedicate this special issue, which was in the course of production as she lay peacefully sleeping, and slipping off into eternity as quietly and serenely as she had lived.

She was a beautiful woman of the Old South—a daughter of Colonel Walter Harrison of Pickett's Brigade of Virginia—"Suh"! Strange as it may seem, one of those "D— Yankees" came to Richmond, wooed and won her after a long secret courtship, in part under moon-bathed magnolias, because family approval of the young Yankee suitor was not to be had. Then, into social exile went a devoted young wife "to love, cherish and obey"—to live her own life out in the country, and raise a family which came along in rapid order to fill her highest wish that "all her troubles be little ones."

She was a Godly woman, spending her spare moments (made possible by our colored gems—"Beckie" Williams, our long time faithful cook, and our old nurse "Mammy" Lizzie, who she "inherited" after having been herself raised under the care of this adored woman) and also all her spare pennies, in getting a little Episcopal Chapel built for our new neighborhood out at the end of the trolley line. For a janitor, to see that our little "Chapel of the Ascension" was cleaned, the prayer books dusted, the fire built in the stove, and the bell tolled to call worshippers, she somehow felt that this "privilege" should go to her first-born—and, I leave it to the reader to imagine who this could have been.

She never knew the feel of wealth, because what little there ever was of it vanished during and after the Civil War which cost Virginia so dearly and put her mother to music teaching to support a widowed family. She was taught, and also taught her own, that money was only a means to an end and that wealth meant nothing in itself. Although every real estate enterprise of the Enslow family which she engineered turned a profit, it was her policy to put most of such gains to the benefit of needy neighbor families, and toward support of the struggling little parish. This side of her personality I must attribute to her great grandfather, the Rt. Reverend Richard Channing Moore—longtime illustrious Bishop of Virginia.

She was a Mother who felt that her children should fight their own battles—and, we had this to do, like it or not. While she didn't raise her sons to be belligerent, she couldn't stand any signs of fear or cowardice. Well can I remember one incident. When a certain red-headed cock of the walk in our neighborhood ("Mike" A. by name) sent her oldest son home once too often with a bloody nose she appointed herself as "master of ceremonies" to see that this thing stopped. So, up the road went the "little general" with her army of one out in front to return battle. With "fair lady" standing by wearing the colors a certain young Knight renewed battle with his sorrel-topped-adversary—and her plan truly worked. Maybe the return engagement was only a draw, but be that as may a certain young mother never again experienced the anguish of seeing on her young hopeful the tell tale blood flecked shirt or damaged proboscus.

This characteristic of my Mother's, exemplified in Virginia's revolution born motto *"Sic Semper Tyrannis,"* seemed rather difficult to explain when learning that *all* of her direct ancestral line were men of the Church of England—clergy or bishops—most of which were outright Tories and returned to England rather than turn against the Crown. And, this statement calls to memory the greatest joke that we children ever had on our Mother. After being asked to accept the regency of a new chapter in the D.A.R. a search in the records disclosed her Tory ancestry, without as much as a single revolutionary fife player on which to hang a right to membership in the D.A.R. So she had to forego the proffered honors—and switch her allegiance wholly to the Colonial Dames.

Like many another Mother, mine was always an inspiration to me, even to the extent of my pledging troth with a "gal" taken more often to be her blood daughter than daughter-in-law. I knew that my Mother was watching whatever progress and success I was making in my chosen field. I knew that she would look forward each month to the arrival of *Water Works & Sewerage*. The honors and recognitions received by me were to her most important. That to me was worth more than any other aspect of such recognitions. And, I was as proud of her, for all that she had been and was, as she possibly could have been of me.

I have often written editorials while rolling along cross-country—but, never one easier—or tougher to write than this, which is being penned as I travel to Richmond from Chicago on this sad mission, while my able associate and friend "Doc" Symons is back there carrying on in the interim, that this special issue may come out as scheduled.

I hope that any possible display of over-sentimentality on this page will not seem out of place. To a Mother a son can owe a lot, and I feel that I could hardly do less than dedicate to mine an issue of a magazine in which she felt so great an interest, and which she had the satisfaction of seeing develop and grow until this very issue is in itself the top production for all time regardless of category—artistry, context, size, lucrativeness.

To my Mother do I dedicate it—

Linn Harrison Enslow

WATER & SEWAGE WORKS

VOL. 93, No. 4 APRIL, 1946

A Gillette Publication

CAVITATION IN PUMPS

By ROBERT W. ANGUS

Consulting Engineer

TORONTO, ONT.

(*Professor Emeritus of Mechanical Engineering, University of Toronto*)

THE destructive action of swiftly flowing water on its containing channels and on engineering structures has been noticed by even the most casual observer who has looked upon the mighty gorges carved by rivers in solid rock, the damaging action of water on bridge piers and on dams, or the destruction wrought by waves. In natural channels, and on concrete structures such as dams, erosion is frequently due to abrasive materials and to large rocks and tree trunks transported by the water. Large rocks often batter the outer surface off concrete and allow the water to dig out the materials below, and heavy tree trunks break the structures and allow eddies to form which may be destructive, as very turbulent water is very quick in its deteriorating effects.

The Pitting of Metals

In this article, however, it is not this important problem that is being discussed, but another matter which more particularly affects the municipal engineer and his water or sewage plant, for machinery also is subject to the same type of damage as the concrete structures. Propellers of boats are often very badly pitted, and lose much of the metal in them, and at least one case is known where the propeller of a destroyer was so badly damaged by water that it had to be replaced after only a few hours running at full speed, and this in a case where the ocean water was the only source of trouble.

All engineers having to do with water turbines are aware of the fact that holes often appear in the metal, particularly in parts of the runner or rotating element, these holes frequently becoming so deep that the machines have to be shut down and the runners built up, or replaced at great expense. This shut down also entails a great loss of power output on account of the long time needed for repairs.

The municipal engineer is much more familiar with the difficulties occurring in valves and in centrifugal pumps, where the water is usually clear and free from harmful chemicals, and the troubles cannot be ascribed to ordinary abrasion or to chemical action. The slower speed pumps ordinarily give little trouble, but the use of high speed motors and direct connected pumps has brought the matter forcibly forward.

As an illustration of what may happen in pumps, the photograph shown in the top of Fig. 1, has been made from part of the shroud cut out of the suction side of an old cast iron impeller, this part being removed from the rest so as to make a good photograph. The shrouds of this impeller were approximately ⅜ in. thick and the photograph shows that holes were eaten entirely through the metal, and that large areas were affected, mostly at the discharge ends of the vanes. The vanes themselves have been partially destroyed and, while this is a very old type of impeller, it shows what can happen in a short period. Incidentally, this was one of the impellers, tried many years ago and later discarded, where half of the vanes only extended half way in, and it is evident

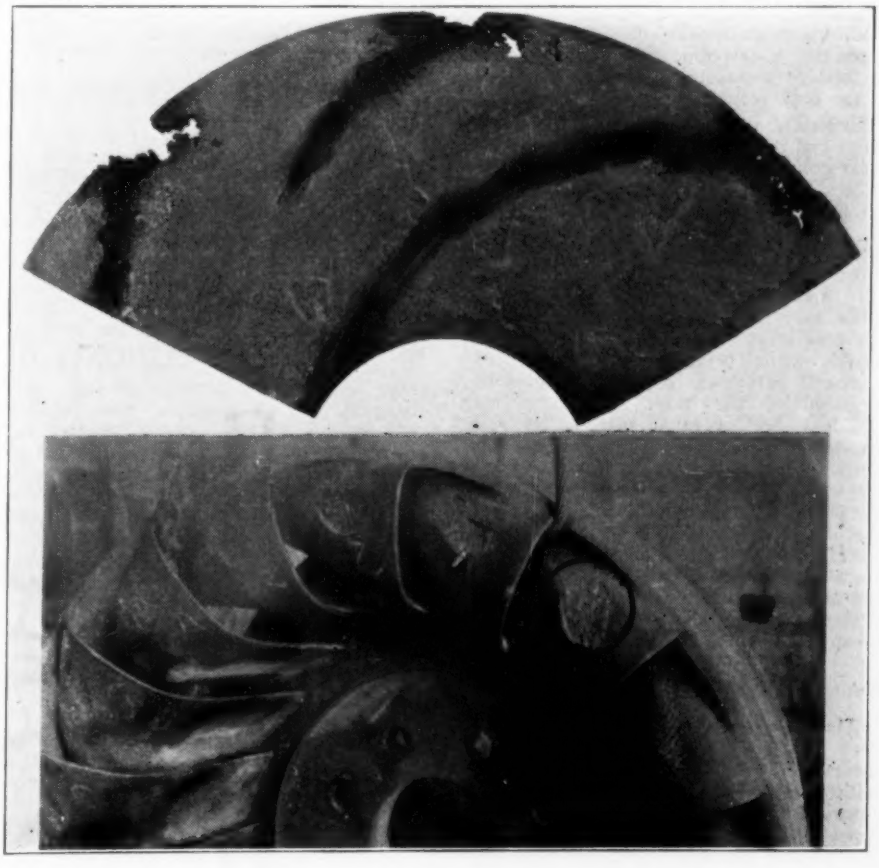

Fig. 1. Damage Done by Cavitation; Top—Part of an Impeller; Bottom—Turbine Runner—The part inside the circle has been chipped out before welding repairs.

that the water decided these short vanes were harmful and removed them, leaving only a faint trace of them to be seen in the figure.

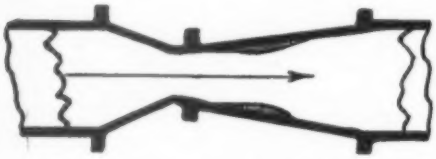

Fig. 2. *Venturi Channel Used in Cavitation Studies*

The bottom portion of Fig. 1 shows a turbine runner damaged by cavitation.

Causes of Damage

At the outset it should be stated that damage to pumps may be due to several causes. In mines the pumps often handle very abrasive materials, and the same is true of pumps used on suction dredges, while in chemical plants the liquids pumped may even dissolve the metals. These phases of the subject seem to be more easily solved than is the case where the liquid is clear and free from harmful chemicals. Assuming the pumps otherwise correctly designed, the protection against abrasives and chemicals is primarily affected by the use of suitable materials in the pump parts. The Standards of the Hydraulic Institute, and also a number of books and catalogues, furnish lists of metals suitable to the different cases. Sometimes even rubber linings are used to provide against wear, and builders have been fairly successful in overcoming wear from abrasion, although, in some cases, even with the most suitable metals, wear is so rapid that a convenient and relatively cheap method of replacement of the worn parts is the only recourse.

Generally speaking, however, water turbines and municipal pumps have to do with clear cold water, as was true for the pump shown in Fig. 1, and yet the damage goes on and causes much anxiety and trouble to those responsible for operating them. The deterioration of turbines has caused most concern, because of their costly nature, and the great loss of power involved when they must be shut down for repairs, for they must often be out of service for weeks while being re-conditioned. The damaged part may have to be completely replaced or the holes welded up with stainless steel or other material at great expense. While water turbines have always been subjected to the damaging effect of the water, it was really the extended use of the low head, high speed reaction machines that made it most acute. Of recent years, many protracted studies have been made on these turbines, by getting data from existing plants and by setting up expensive laboratories in which various types of experiment could be made.

Cavitation—What Is It?

These facts are mentioned because it is very largely from these turbine experiments that we have learned what to do with pumps. The turbine and pump are identical in principle, subject to the same laws of flow and to the same "diseases." The turbine studies showed that high speed machines were more affected than the slower rotating ones, and also that the trouble was greater the higher the machine was placed above the tail water. The action is undoubtedly due to mechanical hammering of drops of water against the metal, thereby eroding the metal or causing cavities, and this action has been given the name of "cavitation."

Strangely enough, cavitation damage does not occur in parts of the machines where the water has a positive pressure against its containing channels, but so far as can be observed, its effect is produced on surfaces where the water pressure is low, often much below atmospheric, and where there may be actual minute separation between the actively flowing water and the metal. If there is large separation, eddies may form and another kind of action results.

The mechanism of cavitation is not fully understood, although photographs with extremely high speed cameras have been taken through glass-sided models, and many turbine and pump builders have a cavitation stand where glass windows may be inserted in the model under examination

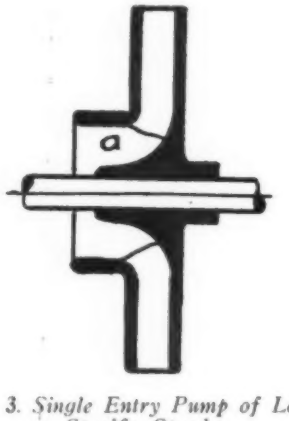

Fig. 3. *Single Entry Pump of Low Specific Speed*

and the action observed by means of a stroboscope.

To give a definite picture of the process, a Venturi tube, Fig. 2, may be used as an illustration inasmuch as the Venturi tube has been very largely used in cavitation studies. The tube illustrated has been shown, for clarity, with an exaggerated taper on the down stream end and, as used in most studies, it has a rectangular throat, instead of a round one; the up and down stream ends are also rectangular with all the rectangles of uniform width, so that the taper is all in one plane; this allows the tube to be made with glass sides.

Picture of Cavitation

For low velocities in the tube, and up to those in ordinary use with the Venturi meter, observations through the glass sides show that the water completely fills both ends and rubs against the walls. But as the velocity increases, a point is reached where the water is unable to expand and completely fill the down stream end, as illustrated, and a foggy area, hatched in the figure, is observed to form above and below the stream, and a little downstream from the throat. Simultaneously with the formation of the foggy area, a noise is heard inside the tube, this noise giving the impression of pieces of shot being projected against the tube wall. If the walls have initially been polished, a few hours' running shows that, in the affected area, the wall surface has become dull, and in prolonged runs will be definitely pitted, even though the metal is hard.

In the tube there is, of course, a decided lowering of pressure near the throat, and high vacua may easily be produced there, although they never reach that of the barometer. The following explanation given of the phenomena seems to be reasonable. The flowing water contains, naturally, a small volume of air and often other gases, and these are probably in the form of small bubbles. In the upstream end these bubbles, which doubtless contain water droplets, are under pressure and of small volume, but as they approach the throat at high velocity, the pressure falls rapidly and the bubbles expand, and if the pressure is low enough, they burst with explosive violence, the contained particles of water flying out against the walls and producing almost incredibly high pressures, as the measurements show. These blows are so hard that no metal can stand against them, although ductile metals like steel resist much better than cast iron. The noise is rather distressing and is the first indication the operator has that cavitation is present in the ordinary machine. While in this case there is clear separation of the water and walls, similar experiments show that the same action occurs without visible separation, in the regions of low pressure.

Photographs and direct observation bear out the probable correctness of this theory, which is further confirmed by the fact that damage in pumps is much more common in regions of low pressure than elsewhere.

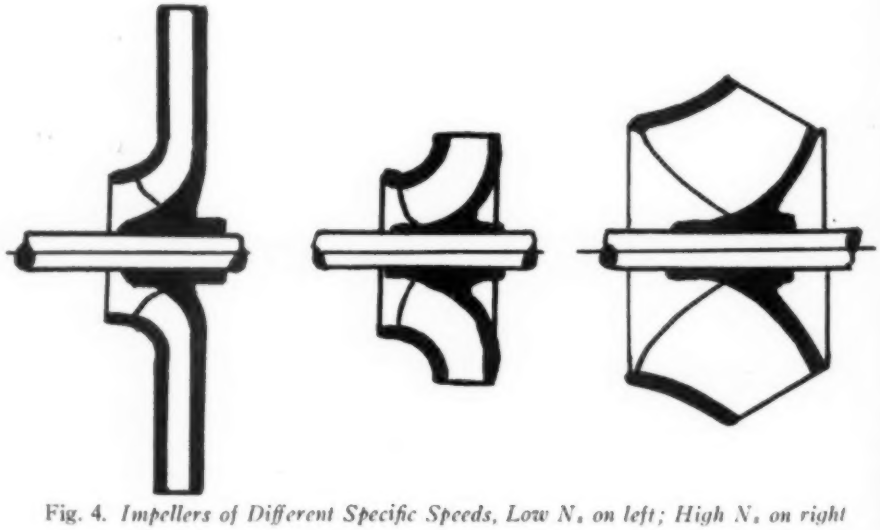

Fig. 4. *Impellers of Different Specific Speeds, Low N_s on left; High N_s on right*

High suction lift is to be avoided, as it produces low pressure in the eye of the pump. But this alone is not sufficient, for the pressure at the inlet end of the impeller vanes is affected by the general shape of the inlet and the rapidity with which the water changes its direction and velocity at entry. Anything causing a rapid acceleration of the water, or a quick change in its direction, will evidently result in a lowering of pressure and a tendency to cavitation. High speed pumps are in more danger than those of lower speed and badly shaped vanes, particularly at the entry end, cause a very quick change in the direction of flow and resulting acceleration of the water with consequent pressure drop. Volatile liquids are more difficult to handle, from this point of view, than heavier ones, and very careful consideration must be given all these points in every case.

Relation of Pump Design to Cavitation

A section of a single stage, single entry centrifugal pump is shown in Fig. 3. Considering the eye of the pump and entry to the impeller, it is seen that, where the pump is set above the well, there will be a low pressure **a** due to this elevation, and this pressure is further lowered by the velocity head at **A** and the resistance loss in the suction pipe up to this point, as well as by the vapour pressure of the liquid.

Undoubtedly, the general proportions of the impeller have an effect on this phenomenon. In large capacity, low head pumps, the entering velocity and the angle through which the water turns as it enters the impeller are usually greater than in high head small capacity machines, and more care must be taken in setting the former. Whatever the explanation, it is well known that the proportions and general shape of the impeller do have a marked influence on the tendency toward cavitation.

Cross-sections, along the shaft axis, of a few typical forms of impellers are shown in Fig. 4, that at the left being for small discharge and high head pumps, while progressing toward the right hand side there is finally shown a form for low head and large discharge. While it is not desirable here to go into the mathematical proof, it may readily be shown that the shape and general proportions of the impeller are indicated, curiously enough, by the numerical value of the expression

$$\frac{N\sqrt{G}}{H^{0.75}}$$

or what is briefly known as the specific speed, where **N** is the rotative speed rpm., **G** the discharge, and **H** the head in ft.

Unfortunately, there is confusion of units with regard to the discharge, which is expressed here in United States gallons per minute, but sometimes Imperial gallons are used, and less frequently cubic feet per second.

In Fig. 4, the left hand pump has the lowest and the right hand pump the highest specific speed of the three.

The Cavitation Constant, Sigma

Experience has shown that the height of the suction lift and the shape, as indicated by the specific speed, are the two main factors entering into the cavitation problem. Largely as a result of his studies on water turbines, Thoma has suggested that the limiting suction lift, for each specific speed, depends on the velocity of the water entering the impeller, on the elevation of

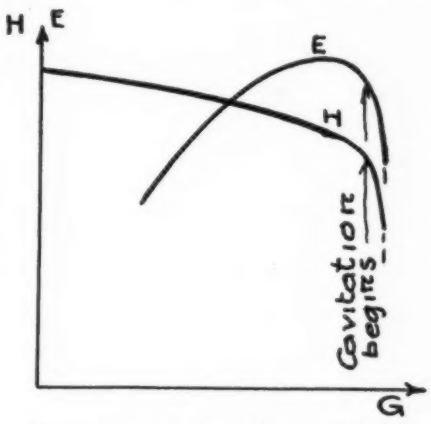

Fig. 6. *Effect of Cavitation on Efficiency and Discharge*

the pump, and on the barometric pressure corrected for the vapor pressure of the fluid being pumped. Thoma's formula, which has been adopted very generally is

$$\text{Sigma} = \frac{B-h}{H}$$

where **B** is the barometric pressure reduced by the vapor pressure of the liquid being pumped, **h** is the height of the center of the impeller above the well surface, plus friction loss and velocity head at the entry to the impeller, and **H** is the head pumped against; all the quantities are in feet and feet of water column. If the barometer reads 30 in. and clear water at 70 deg. F. is being pumped (for which the vapor pressure is .74 in. mercury) then the corresponding value of B is (30—.74) x 13.6/12=33.1 ft. of water.

This number, *sigma*, is called the cavitation constant, the numerator **B—h** is the pressure or vacuum due to the effective lift and the value of sigma is the same whatever units are used, so long as the three quantities are in the same units Evidently the maximum elevation of the pump corresponds to **h=B** ft., for which sigma is zero, and the larger the values of the coefficient the lower the pump must be set, and it may actually be at or below the well level.

Experience of many pump builders in America has been combined, and as a result of data submitted by 24 of them, the Hydraulic Institute of New York has plotted a series of curves from which Fig. 5 has been prepared; this diagram shows the approximate relation between the cavitation coefficient and the specific speed for double suction single stage pumps, but since the constant depends, to a small extent, on the head as well as on the specific speed, the curve is an average for all heads. Similar data are available for other types of pumps. This curve in Fig. 5 shows the minimum value of sigma permissible for safe operation with minimum danger of destructive cavitation; all pumps set with larger sigma, that is with smaller suction lift, are likely to have little trouble if they have been properly designed and built.

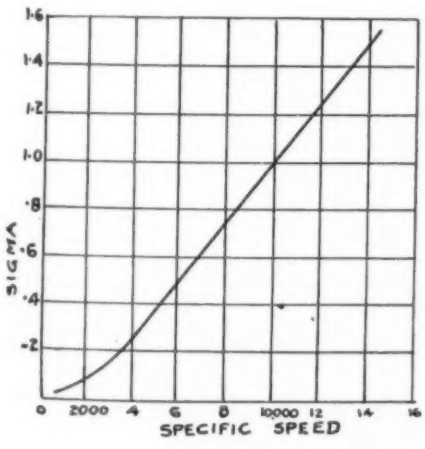

Fig. 5. *Relation Between Specific Speed (N_s) and Possible Suction Lift, as Given by Sigma, for Double Suction Single Stage Pumps.*

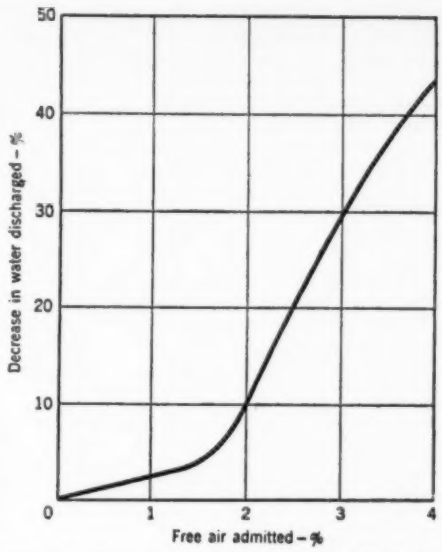

Fig. 7. *Decrease in Discharge of Centrifugal Pump Due to Admission of Air Into Pumps.*

Relation of Sigma to N_s

As an illustration, a double suction pump for 10,000 gpm. (U.S.) at 32 ft. head and 1400 rpm. has a specific speed of 10,000 and would have sigma about equal to unity. If **B**=32 ft., this pump could not have any suction lift and would have to be set below well level to provide for velocity head and resistance. Had the pump been designed for the same conditions but running at half the speed, its specific speed would be 5,000 and the corresponding sigma would be .37; the possible suction lift allowing for friction, etc., would be increased to over 20 ft., permitting the pump to be set at least 16 ft. above the well.

An examination of Fig. 5 shows that sigma increases rapidly with the specific speed, that is, pumps of very large discharge and low head, running at high speed (such as pumps for lifting raw water on to filter beds or for circulating water in condensers) have a large value of sigma and must, therefore, have a small positive and often a negative value of **h**. This means that if cavitation is to be avoided, the pumps must be set close to or actually below the surface of the well. The high head, low discharge pumps may, on the whole, be set much higher. Evidently the lower the speed the less is the danger from cavitation so that, from the cavitation standpoint, low lift pumps particularly should run at as low a speed as possible.

Pumps at or near the sea level may run with higher suction lift than those at higher elevations, and hot water and fluids

which vaporize at low temperatures must have a correspondingly low suction lift. Cavitation is more destructive to cast iron impellers than to steel or bronze, although experiments show that the grade of bronze has a very marked effect.

In computing the specific speed, the discharge and head usually chosen are those corresponding to normal conditions and should, therefore, be those of best efficiency. As pumps are often run at other discharges and heads, it is evident that for these discharges there is a different sigma than for best output. For smaller discharges than normal the specific speed will be decreased and this will correspond to a lower sigma or higher suction head, so that in general the pump is safer from cavitation when running under reduced discharge, although if the discharge is reduced sufficiently there may be some danger of it due to the bad entry and exit conditions in the impeller.

On the other hand, increased discharge renders the pump more liable to cavitation trouble, and practically every pump suffers from it at the very large discharges, that is when running much below best head.

Effect of Cavitation on Pump Efficiency and Discharge

The operating engineer is first aware of cavitation by the noise in the pump and usually vibration accompanying it, but it may easily happen that serious damage may have been done before the noise is disturbing. Probably the best indicator, outside of direct examination of the parts, is a study of the characteristic curves for the pump, which normally have the general shapes shown in Fig. 6 within working ranges of discharge. The head curve **H** and the efficiency curve **E** slope gradually downward. When cavitation begins there is a definite lowering and increase in steepness in the efficiency and discharge curves, the former being the more marked. This is indicated in Fig. 6. Unfortunately, the operator has no exact method of making frequent plots of these curves.

Some experimental pumps have been made with glass sides and the action of the water examined with a stroboscope. The information gained was most valuable and included data on suction conditions, and it was observed that vapor appeared at the outer periphery of the eye of the pump before any change in discharge occurred, particularly for high specific speeds. Of course this air reduces the available inlet area and induces cavitation, so that if cavitation is suspected the pump should be carefully examined, particularly for the larger sized machines. When hot water or oil is being pumped the danger of pitting increases.

Where pumps are operated at high altitudes there must, naturally, be a lower suction lift than if the same pump is working at or below sea level.

Noisy Pump Indicates Cavitation

A noisy pump indicates cavitation, but not always of a very destructive nature. Not long ago the author examined a very large pump working on water supply, but at low head because it was delivering water from a well to the filter beds. This pump was exceedingly noisy when operating at rated discharge, and yet it was a very efficient machine. The noise was so bad that conversation was impossible anywhere near it, and to obviate this difficulty, one or two small holes, little over ⅛ in. diameter, were drilled in the suction pipe close to the eye of the pump. This plan was most effective, almost completely eliminating the noise and making no appreciable change in discharge. Although now for some years in service, this pump shows no deterioration. A word of caution should be given, however, for experiments show that very little air may affect the discharge greatly. As shown in Fig. 7 an amount of 5 per cent by volume would reduce the discharge by many times this per cent.

Many technical articles have appeared on cavitation, one of the most recent being in the October (1945) Transaction of the American Society of Mechanical Engineers. It is the last of several fine articles on this subject written by Dr. A. J. Stepanoff, and will be helpful to those following the technical aspects of the subject.

Charlie Bourgin Made Water Sup't by Montclair

Chas. G. Bourgin, popular young New Jersey water works engineer, has been made superintendent of the Montclair, N. J., Water Dept., succeeding Col. Stuart M. Weaver, who was on leave serving in the U. S. Army. Col. Weaver has tendered his resignation to accept the post of executive vice-president of Ideal Electric & Mfg. Co. of Mansfield, Ohio.

Chas. G. Bourgin

Mr. Bourgin joined the Montclair Water Dept. in 1933 as engineer in charge of the Pumping Station, after graduation from Rensselaer Polytechnic Inst. In 1937 he was advanced to the position of assistant superintendent. Since 1942 Mr. Bourgin has been acting superintendent and manager during Col. Weaver's leave on service in the U. S. Army.

This advancement, which has come to Charlie Bourgin as a young man, represents another laudable recognition of a capable career man in the public service.

R. W. Simpson Joins Gilbert Associates

Head San. Engineering Service

According to an announcement received from Gilbert Associates, Inc., industrial engineers of Reading, Pa., Rolland W. Simpson has been appointed Sanitary Engineer, to head up the sanitary engineering section of the company. The department offers a consulting service for water and sewage treatment plants and industrial waste treatment, and will provide chemicals and standard reagents, check samples regularly, analyze special samples, review monthly operation reports, and advise industry on the design construction, and operation of industrial waste treatment plants.

Prior to joining Gilbert Associates, Mr. Simpson was a Sanitary Engineer attached to the Army Air Corps, stationed at Keesler Field in Biloxi, Miss., from Aug. 1942 until May, 1945. From May, 1945, to Mar. 1, '46, Mr. Simpson was head of the Sanitary Engineering Section of the Post Engineers, Training School, Buckley Field, Colo.

Before joining the U. S. Engineer Corps Simpson was Associate Chemist at the Buffalo (N. Y.) Sewer Authority, where he co-authored a number of articles on sewage chlorination, industrial wastes and sewage research.

E. J. Taylor Appointed Philadelphia Water Bureau Chief

Elbert J. Taylor, a consulting engineer of Philadelphia, has been appointed chief of the Water Bureau of Philadelphia to fill a vacancy created when Martin J. McLaughlin succeeded the late John H. Neeson as Director of Public Works last September.

Appointment to the $8,000 a year job is provisional under Civil Service and the appointee may or may not take an examination, after public hearings are held.

Mr. Taylor, whose firm has been retained by the city for several years for consultation on water problems, is well acquainted with the $18,000,000 improvement program for the city's water systems and the personnel of the bureau.

A. S. Bedell Passes Suddenly

A. S. Bedell, Associate Sanitary Engineer in the Division of Sanitation of the N. Y. State Department of Health in Albany, died suddenly at his home on March 30. Bedell, who was born in Brooklyn and educated at Dartmouth and Massachusetts Institute of Technology, had been Chief of the Bureau of Sewage Treatment for the State of New York for a number of years, and in this capacity had final judgment on all plans for sewage treatment plants in the state.

Arthur S. Bedell

Prior to joining the N. Y. State Dept. of Health in 1925, Mr. Bedell had been a Professor of Mathematics and the Registrar of Roberts College in Istanbul, Turkey, and later was with the Utah Board of Health.

"Art" Bedell, as he was familiarly known to the members of the New York State Sewage Works Association of which he was a Charter Member and Secretary-Treasurer, had been a motive force and guiding hand of that organization since its organization in 1928. Mr. Bedell was also active in the affairs of the Federation of Sewage Works Associations and was president of that organization in 1942. A year later he was elected to Honorary Membership in the Federation. Mr. Bedell was also a member of the Am. Pub. Health Assn. and the Am. Soc. of Civ. Engrs.

He leaves a widow, Mrs. Elsie Bedell, and two daughters, Mrs. James McGraw and Mrs. Stanley Hummel of Albany.

CONCENTRIC ORIFICES

Their Selection, Construction, and Use

By D. R. TAYLOR*
Supt., Water Department
ROANOKE, VA.

THE concentric orifice is one of the simplest forms of differential producers; it is also inexpensive to make and install and suitable for many adaptations.

The purpose of this discussion is to give a simple explanation of the fundamentals of the concentric orifice as a flow measuring device, with typical examples, that may enable the average plant operator to attain a broader understanding and enjoy a wider use of the orifice, one or more of which is being used in the majority of water plants.

Nomenclature and Equations

As an aid to understanding the orifice method of measurement, it is necessary to have some knowledge of the equations and terms involved. These are shown herewith.

C = discharge coefficient
d_1 = diameter of pipe in inches
d_2 = diameter of orifice in inches.
d_f = deflection of manometer liquid in inches
H = head in feet of water
h = head in inches of water
R = ratio of pipe diameter to orifice diameter
Rd = Reynolds number
Qd = gallons per day
Qm = gallons per minute
P.L. = permanent loss of head
S = specific gravity of manometer liquid

$$R = \frac{d_1}{d_2} \qquad \text{Eq. (1)}$$

$$d_2 = \frac{d_1}{R} \qquad \text{Eq. (2)}$$

$$Qd = \frac{28270\, C\, d_1^2 \sqrt{H}}{\sqrt{R^4 - 1}} \qquad \text{Eq. (3)}$$

Fig. 1 shows the dimensions of the orifice plates for installation between standard pipe flanges. The plate should be made of monel metal, stainless steel, or bronze, in that order of preference. If the rim of the orifice (one half of d_1-d_2) is greater than 1-in., an air vent hole of ⅛-in. diameter should be drilled through the top of the orifice plate as close to the top of the inside of the pipe as possible. This vent will prevent an accumulation of air on the upstream side of the orifice plate which would affect the accuracy of the orifice. The vent hole is, of course, not necessary when the installation is made in a vertical pipe. It is important that the upstream edge of the orifice be sharp, with no degree of roundness.

If it is necessary to use an orifice plate thicker than specified in Fig. 1, the downstream edge of the orifice should be bevelled at a 45° angle, until the thickness of the orifice meets the specifications shown. Table I shows the actual inside diameters of pipe and the value of the square of these diameters.

*Recently returned from active duty as Major, Corps of Engineers, A.U.S., Chief of Water and Sewage Section, 4th Service Command.

Taps

The center of the upstream (high pressure) tap for the manometer, etc., should be located one pipe diameter from the upstream face of the orifice plate. The center of the downstream (low pressure) tap should be located one-half pipe diameter from the downstream face of the orifice plate.

The taps in a horizontal pipe run should be in the same plane relative to the axis of the pipe, and on the side of the pipe. The taps should never be made on the top of the pipe. In a vertical pipe run, they may be located at any position around the pipe, but always in the same vertical plane.

$$Qm = \frac{19.632\, C\, d_1^2 \sqrt{H}}{\sqrt{R^4 - 1}} \qquad \text{Eq. (4)}$$

$$Qm = \frac{5.667\, C\, d_1^2 \sqrt{h}}{\sqrt{R^4 - 1}} \qquad \text{Eq. (5)}$$

$$h = \left(\frac{Qm \sqrt{R^4 - 1}}{5.667\, C\, d_1^2} \right)^2 \qquad \text{Eq. (6)}$$

$$\sqrt{R^4 - 1} = \frac{5.667\, C\, d_1^2 \sqrt{h}}{Qm} \qquad \text{Eq. (7)}$$

$$*Rd = \frac{1.953\, Qd}{d_2} \qquad \text{Eq. (8)}$$

$$*Rd = \frac{2812\, Qm}{d_2} \qquad \text{Eq. (9)}$$

*[Ra in equations 8 and 9 is the Reynold's Number for fresh water at 60° F., but is sufficiently accurate for ordinary use over the range of 40° to 80° F.]

TABLE I

Actual Inside Pipe Diameters and the Square of the Diameter

Nominal Diameter (Inches)	WROUGHT IRON				CAST IRON			
	Standard		Extra Heavy		Pit Cast Class B		Centrifugal Class 150	
	d_1	d_1^2	d_1	d_1^2	d_1	d_1^2	d_1	d_1^2
2	2.067	4.272	1.939	3.760				
2½	2.469	6.096	2.323	5.396				
3	3.068	9.413	2.900	8.410				
4	4.026	16.209	3.826	14.638	4.10	16.810	4.12	16.974
6	6.065	36.784	5.761	33.189	6.14	37.700	6.16	37.946
8	7.981	63.696	7.625	58.140	8.03	64.481	8.21	67.404
10	10.020	100.400	9.750	95.063	9.96	99.202	10.16	103.226
12	12.000	144.000	11.750	138.060	11.96	143.040	12.20	148.840
14					13.98	195.440	14.55	211.700
16					16.00	256.000	16.60	275.560

In no case should the taps be less than ¼-in. (iron pipe thread). Suggested maximum tap sizes are ¼-in. for 2-in. pipe; ⅜-in. for 3-in.; ½-in. for 4 to 8-in. inclusive; ⅝-in. for 10-in.; ¾-in. for 12-in.; ⅞-in. for 14-in.; and 1-in. for 16-in. pipe.

The nipples to be inserted in the tapped holes should have all burrs removed from their ends with a pipe reamer or file and they should be inserted no deeper than will cause their ends to be flush with the inside of the pipe. They should not protrude into the inside of the pipe.

Due to the thickness of the flanges, it is difficult to make the downstream tap at the proper location in the case of pipe with a diameter less than 2½ inches. Therefore, for pipe sizes smaller than 2½ inches, it is more satisfactory to purchase from the manufacturers orifice flanges already tapped and complete with the orifice plate.

Distortion of Flow Is Bad

Sudden changes of direction of flow or slight changes in the symmetrical pattern of the water stream may cause marked inaccuracies in the results of flow measurements. For this reason, the orifice should be preceded and followed by minimum lengths of straight pipe. Such lengths are determined by the ratio (R) of pipe diameter to orifice diameter. The suggested minimum lengths expressed in diameters of pipe are shown in Table II.

TABLE II

Minimum Lengths of Straight Pipe for the Upstream and Downstream Sides of Orifices

(Expressed as the Number of Diameters of Pipe.)

Diameter Ratio (R)	Diameters of Pipe	
	Upstream	Downstream
1.25	20	5
1.50	12	4
2.00	7	4
2.50	6½	3½
3.00 and over	6	3

PIPE SIZE	O.D. STANDARD	O.D. (EXTRA HEAVY)	THICKNESS "T"
2"	4"	4¼"	3/32"
2½	4¾	5	3/32
3	5¼	5¾	3/32
4	6¾	7	3/32
5	7⅝	8⅜	3/32
6	8⅝	9¾	3/32
8	10⅞	12	⅛
10	13¼	14⅛	⅛
12	16	16½	3/16
14	17⅝	19	3/16
16	20⅛	21⅛	3/16
18	21½	23⅜	3/16
20	23¾	25⅝	¼
24	28⅛	30⅜	¼

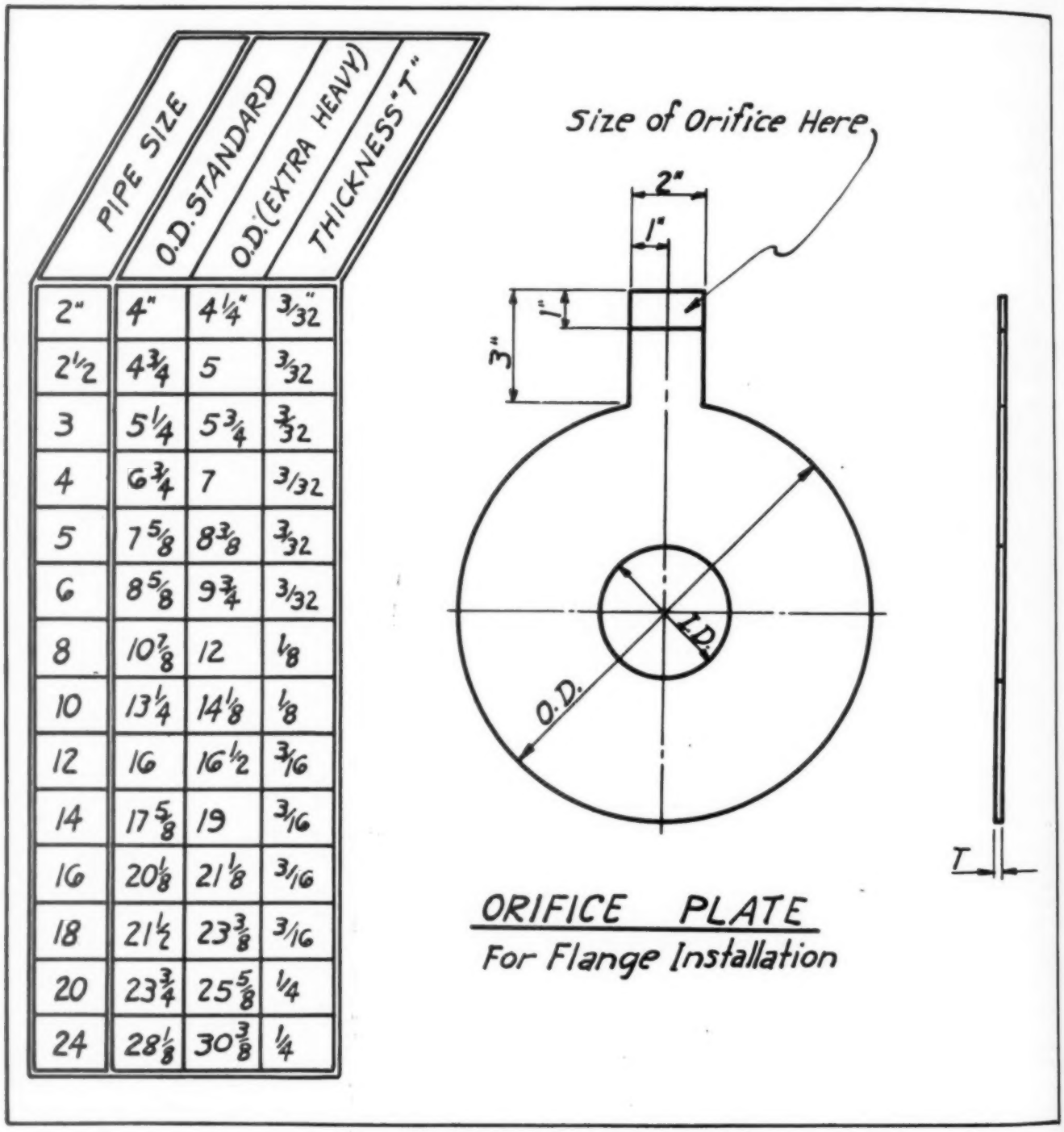

Fig. 1—Dimensions of Orifice Plates for Flange Installation

TABLE IV

Discharge Coefficients of Orifices

Reynolds Number →	Rd 25,000	Rd 50,000	Rd 75,000	Rd 100,000	Rd 150,000	Rd 250,000	Rd 500,000	Rd 1,000,000	Rd 1,500,000
Diameter of Pipe (Inches)	Coefficient where R=1.25								
2			.616	.614	.612	.610	.608		
3			.618	.616	.613	.611	.608	.606	
4				.618	.614	.611	.608	.606	
6				.619	.615	.612	.608	.606	
8				.620	.616	.612	.608	.605	.605
10				.621	.616	.613	.608	.605	.604
12				.622	.617	.613	.608	.605	.604
	Coefficient where R=1.50								
2		.617	.615	.614	.613	.611	.610		
3		.618	.616	.614	.613	.611	.610	.609	
4				.614	.613	.611	.610	.608	
6				.615	.613	.611	.610	.608	
8				.615	.613	.612	.610	.608	.607
10				.615	.613	.612	.610	.609	.607
12				.616	.614	.612	.610	.609	.607
	Coefficient where R=2.00								
2	.612	.609	.608	.607	.606	.605	.604		
3, 4, 6, 8	.612	.609	.608	.607	.606	.605	.604	.603	
10 and 12		.609	.608	.607	.606	.605	.604	.603	.602
	Coefficient where R=2.50								
2 to 12	.608	.605	.603	.602	.601	.601	.600	.599	.598
	Coefficient where R=3.00								
2	.605	.602	.600	.600	.599	.598			
3 and 4	.604	.602	.600	.600	.599	.598	.597		
6 to 12	.604	.602	.600	.600	.599	.598	.597	.597	

It is, in fact, conducive to more positive accuracy if these lengths are exceeded, especially on the upstream side of the orifice, when this length of straight pipe is preceded by two elbows directly or closely connected. If the two elbows are positioned in different planes, the upstream lengths shown in Table II should be increased at least 50 per cent. If the required length cannot be obtained, straightening vanes should be installed 7½ pipe diameters preceding the orifice.

Reynold's Number

The Reynold's number (R_d) is a dimensionless ratio, dependent on a combination of diameter, velocity, density, and viscosity. By experiment it has been found that certain coefficients of discharge prevail for certain values of the Reynold's number. Reynold's number varies with temperature of the water, but for water with a temperature between 40° and 80° F., Equations (8) and (9) are sufficiently accurate for field use. Their use for all temperatures within these limits results in a maximum error of less than two tenths of one per cent and at 60° F. they are correct.

Table IV shows discharge coefficients of orifices for various diameter ratios, pipe diameters, and values of the Reynold's number.

Flow Meter Calibration (Example 1)

It is desired to check the accuracy of an indicating and recording flow meter, which is actuated by an orifice and registers rate of flow in gallons per day, over a range from zero to four million. The pipe is 12-in. class 150 centrifugally cast, cast iron and the orifice diameter is 8 inches. The differential head, between the high and low pressure orifice taps is found to be 7.29 ft., when the meter is registering a rate of 3,000,000 gallons per day.

Given - $d_2 = 8$, $H = 7.29$, From table I, $d_1 = 12.20$, $d_1^2 = 148.84$,

Assume $C = 0.60$ Desired Q_A

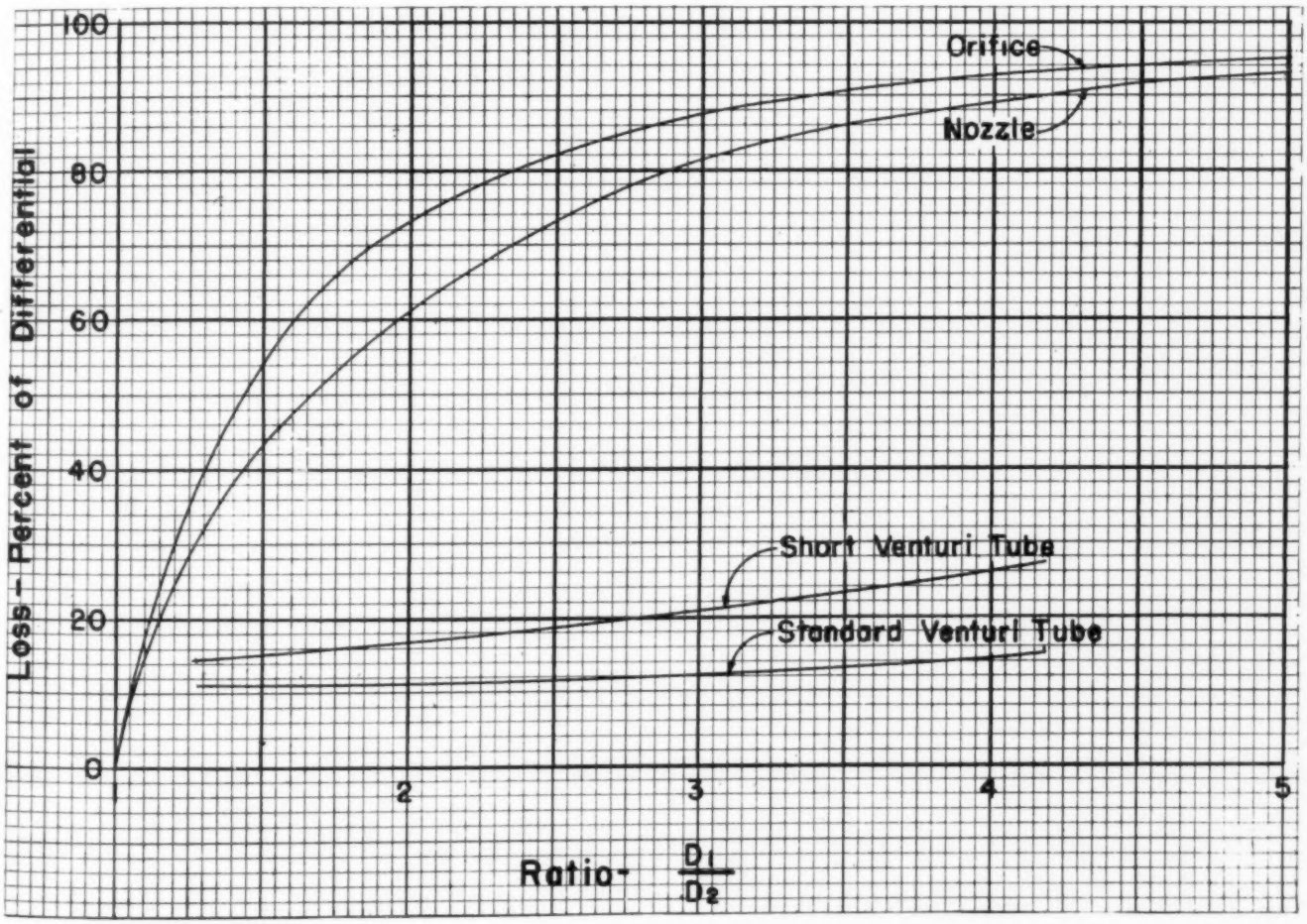

Fig. 2—Permanent Loss of Head for Various Orifice Diameter Ratios (Expressed as Per Cent of Differential)

TABLE III

VALUES OF $\sqrt{R^4-1}$

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.250	1.201	1.204	1.207	1.210	1.213	1.217	1.220	1.223	1.226	1.229
1.260	1.233	1.236	1.239	1.242	1.246	1.249	1.252	1.255	1.259	1.262
1.270	1.265	1.268	1.272	1.275	1.278	1.281	1.284	1.288	1.291	1.294
1.280	1.297	1.300	1.304	1.307	1.310	1.314	1.317	1.320	1.323	1.326
1.290	1.330	1.333	1.337	1.340	1.343	1.346	1.349	1.353	1.356	1.359
1.300	1.362	1.366	1.369	1.372	1.375	1.379	1.382	1.385	1.388	1.391
1.310	1.395	1.398	1.401	1.405	1.408	1.411	1.414	1.418	1.421	1.424
1.320	1.427	1.430	1.433	1.437	1.440	1.443	1.446	1.449	1.453	1.456
1.330	1.459	1.462	1.466	1.469	1.472	1.475	1.478	1.482	1.485	1.488
1.340	1.491	1.495	1.498	1.501	1.504	1.508	1.511	1.514	1.517	1.520
1.350	1.524	1.527	1.530	1.533	1.537	1.540	1.543	1.546	1.549	1.553
1.360	1.556	1.559	1.562	1.566	1.569	1.572	1.575	1.579	1.582	1.585
1.370	1.588	1.592	1.595	1.598	1.601	1.605	1.608	1.611	1.614	1.617
1.380	1.621	1.624	1.627	1.630	1.634	1.637	1.640	1.643	1.647	1.650
1.390	1.653	1.656	1.660	1.663	1.666	1.669	1.673	1.676	1.679	1.682
1.400	1.686	1.689	1.692	1.695	1.699	1.702	1.705	1.709	1.712	1.715
1.410	1.718	1.722	1.725	1.728	1.731	1.735	1.738	1.741	1.744	1.748
1.420	1.751	1.754	1.757	1.761	1.764	1.767	1.771	1.774	1.777	1.780
1.430	1.784	1.787	1.790	1.794	1.797	1.800	1.803	1.807	1.810	1.813
1.440	1.817	1.820	1.823	1.826	1.830	1.833	1.836	1.840	1.843	1.846
1.450	1.849	1.853	1.856	1.859	1.863	1.866	1.869	1.873	1.876	1.879
1.460	1.882	1.886	1.889	1.892	1.896	1.899	1.902	1.906	1.909	1.912
1.470	1.916	1.919	1.922	1.926	1.929	1.932	1.936	1.939	1.942	1.945
1.480	1.949	1.952	1.955	1.959	1.962	1.965	1.969	1.972	1.975	1.979
1.490	1.982	1.985	1.989	1.992	1.996	1.999	2.002	2.006	2.009	2.012
1.500	2.016	2.019	2.022	2.026	2.029	2.032	2.036	2.039	2.042	2.046
1.510	2.049	2.052	2.056	2.059	2.063	2.066	2.069	2.073	2.076	2.079
1.520	2.083	2.086	2.090	2.093	2.096	2.100	2.103	2.106	2.110	2.113
1.530	2.117	2.120	2.123	2.127	2.130	2.134	2.137	2.140	2.144	2.147
1.540	2.150	2.154	2.157	2.161	2.164	2.167	2.171	2.174	2.178	2.181
1.550	2.184	2.188	2.191	2.195	2.198	2.202	2.205	2.208	2.212	2.215
1.560	2.219	2.222	2.226	2.229	2.232	2.236	2.239	2.243	2.246	2.250
1.570	2.253	2.256	2.260	2.263	2.267	2.270	2.274	2.277	2.280	2.284
1.580	2.287	2.291	2.294	2.298	2.301	2.305	2.308	2.312	2.315	2.318
1.590	2.322	2.325	2.329	2.332	2.336	2.339	2.343	2.346	2.350	2.353
1.600	2.357	2.360	2.364	2.367	2.371	2.374	2.378	2.381	2.384	2.388
1.610	2.391	2.395	2.398	2.402	2.405	2.409	2.412	2.416	2.419	2.423
1.620	2.426	2.430	2.433	2.437	2.440	2.444	2.447	2.451	2.455	2.458
1.630	2.462	2.465	2.469	2.472	2.476	2.479	2.483	2.486	2.490	2.493
1.640	2.497	2.500	2.504	2.507	2.511	2.515	2.518	2.522	2.525	2.529
1.650	2.532	2.536	2.539	2.543	2.546	2.550	2.554	2.557	2.561	2.564
1.660	2.568	2.571	2.575	2.578	2.582	2.586	2.589	2.593	2.596	2.600
1.670	2.603	2.607	2.611	2.614	2.618	2.621	2.625	2.629	2.632	2.636
1.680	2.639	2.643	2.647	2.650	2.654	2.657	2.661	2.665	2.668	2.672
1.690	2.675	2.679	2.683	2.686	2.690	2.693	2.697	2.701	2.704	2.708
1.700	2.711	2.715	2.719	2.722	2.726	2.730	2.733	2.737	2.741	2.744
1.710	2.748	2.751	2.755	2.758	2.762	2.766	2.770	2.773	2.777	2.781

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.720	2.784	2.788	2.792	2.795	2.799	2.803	2.806	2.810	2.814	2.817
1.730	2.821	2.825	2.828	2.832	2.836	2.839	2.843	2.847	2.850	2.854
1.740	2.858	2.861	2.865	2.869	2.872	2.876	2.880	2.884	2.887	2.891
1.750	2.895	2.898	2.902	2.906	2.909	2.913	2.917	2.921	2.924	2.928
1.760	2.932	2.935	2.939	2.943	2.947	2.950	2.954	2.958	2.962	2.965
1.770	2.969	2.973	2.977	2.980	2.984	2.988	2.991	2.995	2.999	3.003
1.780	3.006	3.010	3.014	3.018	3.022	3.025	3.029	3.033	3.037	3.040
1.790	3.044	3.048	3.052	3.055	3.059	3.063	3.067	3.070	3.074	3.078
1.800	3.082	3.086	3.089	3.093	3.097	3.101	3.105	3.108	3.112	3.116
1.810	3.120	3.124	3.127	3.131	3.135	3.139	3.143	3.146	3.150	3.154
1.820	3.158	3.162	3.166	3.169	3.173	3.177	3.181	3.185	3.188	3.192
1.830	3.196	3.200	3.204	3.208	3.211	3.215	3.219	3.223	3.227	3.231
1.840	3.235	3.238	3.242	3.246	3.250	3.254	3.258	3.262	3.265	3.269
1.850	3.273	3.277	3.281	3.285	3.289	3.293	3.296	3.300	3.304	3.308
1.860	3.312	3.316	3.320	3.324	3.328	3.331	3.335	3.339	3.343	3.347
1.870	3.351	3.355	3.359	3.363	3.367	3.370	3.374	3.378	3.382	3.386
1.880	3.390	3.394	3.398	3.402	3.406	3.410	3.414	3.417	3.421	3.425
1.890	3.429	3.433	3.437	3.441	3.445	3.449	3.453	3.457	3.461	3.465
1.900	3.469	3.473	3.477	3.481	3.485	3.489	3.493	3.496	3.500	3.504
1.910	3.508	3.512	3.516	3.520	3.524	3.528	3.532	3.536	3.540	3.544
1.920	3.548	3.552	3.556	3.560	3.564	3.568	3.572	3.576	3.580	3.584
1.930	3.588	3.592	3.596	3.600	3.604	3.608	3.612	3.616	3.620	3.624
1.940	3.628	3.632	3.636	3.640	3.644	3.648	3.653	3.657	3.661	3.665
1.950	3.669	3.673	3.677	3.681	3.685	3.689	3.693	3.697	3.701	3.705
1.960	3.709	3.713	3.717	3.721	3.725	3.730	3.734	3.738	3.742	3.746
1.970	3.750	3.754	3.758	3.762	3.766	3.770	3.774	3.778	3.783	3.787
1.980	3.791	3.795	3.799	3.803	3.807	3.811	3.815	3.819	3.824	3.828
1.990	3.832	3.836	3.840	3.844	3.848	3.852	3.857	3.861	3.865	3.869
2.000	3.873	3.877	3.881	3.885	3.890	3.894	3.898	3.902	3.906	3.910
2.010	3.914	3.919	3.923	3.927	3.931	3.935	3.939	3.943	3.948	3.952
2.020	3.956	3.960	3.964	3.968	3.973	3.977	3.981	3.985	3.989	3.994
2.030	3.998	4.002	4.006	4.010	4.015	4.019	4.023	4.027	4.031	4.035
2.040	4.040	4.044	4.048	4.052	4.057	4.061	4.065	4.069	4.073	4.078
2.050	4.082	4.086	4.090	4.094	4.099	4.103	4.107	4.111	4.116	4.120
2.060	4.124	4.128	4.133	4.137	4.141	4.145	4.150	4.154	4.158	4.162
2.070	4.167	4.171	4.175	4.179	4.184	4.188	4.192	4.196	4.201	4.205
2.080	4.209	4.214	4.218	4.222	4.226	4.231	4.235	4.239	4.244	4.248
2.090	4.252	4.256	4.261	4.265	4.269	4.274	4.278	4.282	4.287	4.291
2.100	4.295	4.299	4.304	4.308	4.312	4.317	4.321	4.325	4.330	4.334
2.110	4.338	4.343	4.347	4.351	4.356	4.360	4.364	4.369	4.373	4.377
2.120	4.382	4.386	4.391	4.395	4.399	4.404	4.408	4.412	4.417	4.421
2.130	4.425	4.430	4.434	4.438	4.443	4.447	4.452	4.456	4.460	4.465
2.140	4.469	4.473	4.478	4.482	4.487	4.491	4.495	4.500	4.504	4.509
2.150	4.513	4.517	4.522	4.526	4.531	4.535	4.540	4.544	4.548	4.553
2.160	4.557	4.562	4.566	4.570	4.575	4.579	4.584	4.588	4.593	4.597
2.170	4.602	4.606	4.610	4.615	5.619	4.624	4.628	4.633	4.637	4.642
2.180	4.646	4.651	4.655	4.659	4.664	4.668	4.673	4.677	4.682	4.686

TABLE III (Continued)

VALUES OF $\sqrt{R^4 - 1}$

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.190	4.691	4.695	4.700	4.704	4.709	4.713	4.718	4.722	4.727	4.731
2.200	4.736	4.740	4.745	4.759	4.754	4.758	4.763	4.767	4.772	4.776
2.210	4.781	4.785	5.790	4.794	4.799	4.803	4.808	4.812	4.817	4.821
2.220	4.826	4.830	4.835	4.840	4.844	4.849	4.853	4.858	4.862	4.867
2.230	4.871	4.876	4.880	4.885	4.890	4.894	4.899	4.903	4.908	4.912
2.240	4.917	4.922	4.926	4.931	4.935	4.940	4.944	4.949	4.954	4.958
2.250	4.963	4.967	4.972	4.977	4.981	4.986	4.990	4.995	5.000	5.004
2.260	5.009	5.013	5.018	5.023	5.027	5.032	5.036	5.041	5.046	5.050
2.270	5.055	5.060	5.064	5.069	5.073	5.078	5.083	5.087	5.092	5.097
2.280	5.101	5.106	5.111	5.115	5.120	5.125	5.129	5.134	5.139	5.143
2.290	5.148	5.153	5.157	5.162	5.167	5.171	5.176	5.181	5.185	5.190
2.300	5.195	5.199	5.204	5.209	5.213	5.218	5.223	5.227	5.232	5.237
2.310	5.242	5.246	5.251	5.256	5.260	5.265	5.270	5.275	5.279	5.284
2.320	5.289	5.293	5.298	5.303	5.308	5.312	5.317	5.322	5.327	5.331
2.330	5.336	5.341	5.346	5.350	5.355	5.360	5.365	5.369	5.374	5.379
2.340	5.384	5.388	5.393	5.398	5.403	5.407	5.412	5.417	5.422	5.426
2.350	5.431	5.436	5.441	5.446	5.450	5.455	5.460	5.465	5.470	5.474
2.360	5.479	5.484	5.489	5.494	5.498	5.503	5.508	5.513	5.518	5.522
2.370	5.527	5.532	5.537	5.542	5.546	5.551	5.556	5.561	5.566	5.571
2.380	5.575	5.580	5.585	5.590	5.595	5.600	5.605	5.609	5.614	5.619
2.390	5.624	5.629	5.634	5.639	5.643	5.648	5.653	5.658	5.663	5.668
2.400	5.673	5.677	5.682	5.687	5.692	5.697	5.702	5.707	5.712	5.717
2.410	5.721	5.726	5.731	5.736	5.741	5.746	5.751	5.756	5.761	5.765
2.420	5.770	5.775	5.780	5.785	5.790	5.795	5.800	5.805	5.810	5.815
2.430	5.820	5.825	5.829	5.834	5.839	5.844	5.849	5.854	5.859	5.864
2.440	5.869	5.874	5.879	5.884	5.889	5.894	5.899	5.904	5.909	5.914
2.450	5.919	5.924	5.929	5.934	5.939	4.944	5.949	5.953	5.958	5.963
2.460	5.968	5.973	5.978	5.983	5.988	5.993	5.998	6.003	6.008	6.013
2.470	6.018	6.023	6.028	6.033	6.038	6.043	6.048	6.053	6.058	6.063
2.480	6.069	6.074	6.079	6.084	6.089	6.094	6.099	6.104	6.109	6.114
2.490	6.119	6.124	6.129	6.134	6.139	6.144	6.149	6.154	6.159	6.164
2.500	6.169	6.175	6.180	6.185	6.190	6.195	6.200	6.205	6.210	6.215
2.510	6.220	6.225	6.230	6.236	6.241	6.246	6.251	6.256	6.261	6.266
2.520	6.271	6.276	6.281	6.287	6.292	6.297	6.302	6.307	6.312	6.317
2.530	6.322	6.327	6.333	6.338	6.343	6.348	6.353	6.358	6.363	6.369
2.540	6.374	6.379	6.384	6.389	6.394	6.399	6.405	6.410	6.415	6.420
2.550	6.425	6.430	6.436	6.441	6.446	6.451	6.456	6.461	6.467	6.472
2.560	6.477	6.482	6.487	6.492	6.498	6.503	6.508	6.513	6.518	6.524
2.570	6.529	6.534	6.539	6.544	6.550	6.555	6.560	6.565	6.570	6.576
2.580	6.581	6.586	6.591	6.597	6.602	6.607	6.612	6.617	6.623	6.628
2.590	6.633	6.638	6.644	6.649	6.654	6.659	6.665	6.670	6.675	6.680
2.600	6.686	6.691	6.696	6.701	6.707	6.712	6.717	6.722	6.728	6.733
2.610	6.738	6.744	6.749	6.754	6.759	6.765	6.770	6.775	6.781	6.786
2.620	6.791	6.796	6.802	6.807	6.812	6.818	6.823	6.828	6.834	6.839
2.630	6.844	6.850	6.855	6.860	6.866	6.871	6.876	6.882	6.887	6.892
2.640	6.897	6.903	6.908	6.914	6.919	6.924	6.930	6.935	6.940	6.946
2.650	6.951	6.956	6.962	6.967	6.972	6.978	6.983	6.988	6.994	6.999

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.660	7.005	7.010	7.015	7.021	7.026	7.032	7.037	7.042	7.048	7.053
2.670	7.058	7.064	7.069	7.075	7.080	7.085	7.091	7.096	7.102	7.107
2.680	7.113	7.118	7.123	7.129	7.134	7.140	7.145	7.150	7.156	7.161
2.690	7.167	7.172	7.178	7.183	7.188	7.194	7.199	7.205	7.210	7.216
2.700	7.221	7.227	7.232	7.237	7.243	7.248	7.254	7.259	7.265	7.270
2.710	7.276	7.281	7.287	7.292	7.298	7.303	7.309	7.314	7.320	7.325
2.720	7.331	7.336	7.342	7.347	7.353	7.358	7.364	7.369	7.375	7.380
2.730	7.386	7.391	7.397	7.402	7.408	7.413	7.419	7.424	7.430	7.435
2.740	7.441	7.446	7.452	7.457	7.463	7.468	7.474	7.480	7.485	7.491
2.750	7.496	7.502	7.507	7.513	7.518	7.524	7.529	7.535	7.541	7.546
2.760	7.552	7.557	7.563	7.568	7.574	7.580	7.585	7.591	7.596	7.602
2.770	7.607	7.613	7.619	7.624	7.630	7.635	7.641	7.647	7.652	7.658
2.780	7.663	7.669	7.675	7.680	7.686	7.692	7.697	7.703	7.708	7.714
2.790	7.720	7.725	7.731	7.737	7.742	7.748	7.753	7.759	7.765	7.770
2.800	7.776	7.782	7.787	7.793	7.799	7.804	7.810	7.816	7.821	7.827
2.810	7.833	7.838	7.844	7.850	7.855	7.861	7.867	7.872	7.878	7.884
2.820	7.889	7.895	7.901	7.906	7.912	7.918	7.923	7.929	7.935	7.941
2.830	7.946	7.952	7.958	7.963	7.969	7.975	7.981	7.986	7.992	7.998
2.840	8.003	8.009	8.015	8.021	8.026	8.032	8.038	8.044	8.049	8.055
2.850	8.061	8.066	8.072	8.078	8.084	8.090	8.095	8.101	8.107	8.113
2.860	8.118	8.124	8.130	8.136	8.141	8.147	8.153	8.159	8.164	8.170
2.870	8.176	8.182	8.188	8.193	8.199	8.205	8.211	8.217	8.222	8.228
2.880	8.234	8.240	8.246	8.251	8.257	8.263	8.269	8.275	8.280	8.286
2.890	8.292	8.298	8.304	8.310	8.315	8.321	8.327	8.333	8.339	8.345
2.900	8.350	8.356	8.362	8.368	8.374	8.380	8.385	8.391	8.397	8.403
2.910	8.409	8.415	8.421	8.426	8.432	8.438	8.444	8.450	8.456	8.462
2.920	8.468	8.473	8.479	8.485	8.491	8.497	8.503	8.509	8.515	8.521
2.930	8.526	8.532	8.538	8.544	8.550	8.556	8.562	8.568	8.574	8.580
2.940	8.586	8.591	8.597	8.603	8.609	8.615	8.621	8.627	8.633	8.639
2.950	8.645	8.651	8.657	8.663	8.669	8.675	8.681	8.687	8.692	8.698
2.960	8.704	8.710	8.716	8.722	8.728	8.734	8.740	8.746	8.752	8.758
2.970	8.764	8.770	8.776	8.782	8.788	8.794	8.800	8.806	8.812	8.818
2.980	8.824	8.830	8.836	8.842	8.848	8.854	8.860	8.866	8.872	8.878
2.990	8.884	8.890	8.896	8.902	8.908	8.914	8.920	8.926	8.932	8.938
3.000	8.944	8.950	8.956	8.962	8.968	8.975	8.981	8.987	8.993	8.999
3.010	9.005	9.011	9.017	9.023	9.029	9.035	9.041	9.047	9.053	9.059
3.020	9.065	9.071	9.078	9.084	9.090	9.096	9.102	9.108	9.114	9.120
3.030	9.126	9.133	9.138	9.145	9.151	9.157	9.163	9.169	9.175	9.181
3.040	9.187	9.193	9.200	9.206	9.212	9.218	9.224	9.230	9.236	9.243
3.050	9.249	9.255	9.261	9.267	9.273	9.279	9.285	9.292	9.298	9.304
3.060	9.310	9.316	9.322	9.329	9.335	9.341	9.347	9.353	9.359	9.366
3.070	9.372	9.378	9.384	9.390	9.396	9.403	9.409	9.415	9.421	9.427
3.080	9.434	9.440	9.446	9.452	9.458	9.465	9.471	9.477	9.483	9.489
3.090	9.496	9.502	9.508	9.514	9.520	9.527	9.533	9.539	9.545	9.552
3.100	9.558	9.564	9.570	9.577	9.583	9.589	9.595	9.602	9.608	9.614

By Eq. (1), $R = \frac{12.20}{8} = 1.525$

From Table III, $\sqrt{R^4-1} = 2.1$

By Eq.(3), $Q_d = \frac{28270 \times 0.60 \times 148.84 \times 2.7}{2.1} = 3,245,900$

By Eq.(8), $R_d = \frac{1.953 \times 3,245,900}{8} = 792,400$

From Table IV,
by interpolating it is found that for 12" pipe centrifugally cast when R = 1.50 and R_d = 792,400, that the C value is 0.6094 instead of 0.60 (assumed), therefore,

$Q_d = 3,245,900 \times \frac{0.60942}{0.60} = 3,296,861$

Inasmuch as the meter was registering only 3,000,000, it was under-registering an amount calculated as follows:

$$\text{Error} = \frac{3,296,861 - 3,000,000}{3,296,861} = 9.0 \text{ per cent.}$$

In other words the meter was registering 9 per cent low at the 3 mgd. rate. Now, the rate of flow should be varied and similar tests made at other rates of flow, over the entire range of the instrument, for accurate calibration. For rates of flow in gallons per minute, Eq. (4) and Eq. (5) may be used.

Selecting the Size of Orifice
(Example 2)

Three pumps with capacities of 50, 100, and 150 gallons per minute are controlled by pressure switches and operate separately or simultaneously, depending on the demand. It is desired to install an orifice to operate a proportional chemical feeder, which is differentially actuated. The feeder will not operate with a differential of less than four inches of water. On the other hand, it is not desired to create any more artificial head than is necessary, on the pumps. The discharge pipe from the station is 6-in. class 150, centrifugal cast iron.

Given - Minimum $Q_m = 50$
Maximum $Q_m = 50 + 100 + 150 = 300$
Minimum $h = 4$ Assume $C = 0.61$
From Table I, $d_1 = 6.16$ and $d_1^2 = 37.946$

Desired - Orifice diameter d_2 to obtain an h of 4 inches at minimum Q_m and lowest possible h at maximum Q_m

By Eq.(7), $\sqrt{R^4-1} = \frac{5.667 \times 0.61 \times 37.946 \times 2}{50} = 5.25$

From Table III,
it will be seen that for $\sqrt{R^4-1} = 5.25$ that R = 2.312
By Eq.(2), $d_2 = \frac{6.16}{2.312} = 2.66$ in.

The loss of head for the maximum Q_m should next be determined.

By Eq.(6), $h = \left(\frac{300 \times 5.25}{5.667 \times .61 \times 37.946}\right)^2 = 144$ in.

This represents a momentary loss of head, but all differential producers recover part of the temporary loss of head, which they produce.

Fig. 2 shows the permanent loss of head through various differential producers, expressed in per cent of differential. Such head loss is dependent on the diameter ratio (R) and it will be seen from Fig. 2 that the permanent loss for R = 2.312 is only 79 per cent of the momentary orifice differential. Therefore, in this case the permanent loss of head at 300 gpm. is

$$\text{P.L.} = 0.79 \times 144 = 113.76 \text{ in.}$$

For some problems of this nature, that of determining the size of the orifice, to obtain some desired differential, it is sufficiently accurate to use a coefficient of 0.61 and it is not necessary to determine Q_m and R_d and recalculate with the resulting exact coefficient, because the average error effected by not so doing will be less than three tenths of one per cent.

It is customary practice not to impose more than 100 inches of differential head loss on pumps at maximum pumping capacity, if such can be avoided. It is often found, however, that the pump in question is operating at a total dynamic head of several feet below that for which it was designed and is delivering more than its designed capacity. In such a case the imposition of some artificial head may do no harm and may even be beneficial and actually conducive to pumping economy.

If this is not found to be the case, and the calculated permanent loss of head (P.L.) through the proposed orifice at the maximum rate is found to be too great, after considering all pertinent circumstances, then a Venturi tube or a velocity type meter, whose permanent head loss is low (see Fig. 2) or some other type of metering equipment should be used.

Comparing the Venturi Tube and the Orifice Meter

All formulas given are equally applicable to the Venturi tube and the flow nozzle. The only difference is in the value of the coefficient (C) and the permanent loss of head. An average coefficient of 0.977 may be assumed for the standard Herschel (long) Venturi tube; however, for extremely accurate calibration the value of C. for the tube in question should be secured from the manufacturer.

With the same conditions as shown in Example 2, the results with a Venturi tube instead of an orifice would be as follows, assuming C equal to 0.977.

By Eq.(7), $\sqrt{R^4-1} = \frac{5.667 \times .977 \times 37.946 \times 2}{50} = 8.4$

From Table III, R = 2.9085

By Eq.(2), $d_2 = \frac{6.16}{2.9085} = 2.118$ in.

For $Q_m = 300$, by Eq. (6);

$h = \left(\frac{300 \times 8.4}{5.667 \times .977 \times 37.946}\right)^2 = 144$ in.

From Fig. 2, P.L. = 0.20 x 144 = 28.8 in., which would be a very acceptable permanent loss.

If the purpose of the installation is for chemical feeding only and does not include the possibilities of flow measurement, it may be more economical to use a variable differential orifice, which is designed on the principle of a horizontal swing check valve and produces proportionate differential, but the curve is flatter than that of the fixed orifice. Information concerning this type of orifice may be secured from the McKays Co. of Saint Paul, Minn.

Standard orifice plates may be purchased with any size orifice, from any of the flow measuring equipment manufacturers. if it is preferred not to make them.

Chlorine Control and Meter Combination
(Example 3)

A source of water supply consists of six wells with capacities of 100 gpm. each, all discharging through an 8-in. common discharge of class 150 centrifugal cast iron pipe. As a contrast to the problem in Example 2, these wells are operated in groups of either three or six simultaneously. It is desired to install an automatic chlorinator and a flow meter, both to be actuated by the same orifice. It will be necessary to install a separate pair of taps (on opposite sides of the pipe) for each piece of equipment. The flow meter requires a differential of 12 inches at 300 gpm.

Given - Minimum $Q_m = 300$ at $h = 12$ in.
Maximum $Q_m = 600$
From Table I, $d_1 = 8.21$, and $d_1^2 = 67.404$;
Assume $C = 0.61$

Desired - d_2 and h when $Q_m = 600$

By Eq.(7), $\sqrt{R^4-1} = \frac{5.667 \times 0.61 \times 67.404 \times 3.464}{300} = 2.690$

From Table III, R = 1.694 and by Eq.(2) $d_2 = \frac{8.21}{1.694} = 4.847$ in.

For maximum flow, $Q_m = 600$

By Eq. (6), $h = \left(\frac{600 \times 2.69}{5.667 \times 0.61 \times 67.404}\right)^2 = 48$ in.

From Fig. 2, P.L. = 0.64 x 48 = 30.7 in.

Testing Pumps
(Example 4)

A pump station consists of three pumps with rated capacities of 350, 700, and 750 gpm. The common discharge is 10-in. class 150 centrifugal cast iron pipe. A 13¼-in. x 6.655-in. orifice plate (see Fig. 1) has been installed to operate an automatic chlorinator. There is no measuring equipment. It is desired to determine the output of the pumps under actual operating conditions. The 700 gpm. pump will be tested first.

Given - $d_2 = 6.655$; From Table I, $d_1 = 10.16$ and $d_1^2 = 103.226$

With a manometer h is found to be 18".

Assume $C = 0.61$ Desired - Q_m

By Eq.(1) $R = \frac{10.16}{6.655} = 1.527$

From Table III, $\sqrt{R^4 - 1} = 2.106$

By Eq.(5) $Q_m = \frac{5.667 \times 0.61 \times 103.226 \times 4.243}{2.106} = 719$

By Eq.(9), $R_d = \frac{2812 \times 719}{6.655} = 303,800$

From Table IV, for $R = 1.50$, and $R_d = 303,800$ for 10 in. pipe it is found that $C = 0.6116$

This value is so close to the value of $C = 0.61$ which was used, that no correction is necessary and it may be considered that the discharge of the pump is 719 gpm.

The other two pumps may be tested in a similar manner, separately or while operating simultaneously or in any number of combinations. With the use of a pressure gage and a vacuum gage (or other manometer), the total dynamic head under which the pumps are operating could easily be determined and that information, together with the output, would enable the operator to ascertain from the manufacturer's head-capacity characteristics curve, whether or not the pumps meet the specifications under which they were purchased.

Accuracies

Ratios (R) of less than 1.40 should be avoided whenever possible and ratios of less than 1.25 should never be used, for accurate flow measurement. An accuracy of plus or minus one per cent may be expected with ratios of 1.40 or greater and of plus or minus two per cent with ratios from 1.25 to 1.40. With ratios under 1.25, there are so many unreliable conditions, that if such ratios are unavoidable, the orifice should be calibrated "in place" over its entire range.

With respect to accuracy, one other warning should be given. When using or checking old flow measuring equipment, where scale, tuberculation, or wear is known or suspected, actual measurements should be made of d_1 and d_2. In the case of an orifice, if the upstream edge of the orifice becomes rounded, it should be replaced. A keen sharp edge is the first requirement of an orifice for accurate flow measurement.

The Relation of Flow and Head Differential
(Examples 5 and 6)

Differential head varies directly with the square of the flow, that is, $h_2 = h_1 \left(\frac{Q_2}{Q_1}\right)^2$ ——— Eq.(10)

After the differential head has been determined for one rate of flow, the differential head for any other rate of flow may be easily determined by the above simple formula.

With a flow of 500 gpm. if the differential head is found to be 12 inches, what will the differential head be for a flow of 1000 gpm.?

Given - $Q_1 = 500$, $h_1 = 12$ in. $Q_2 = 1000$, Desired - h_2

By Eq.(10); $h_2 = 12\left(\frac{1000}{500}\right)^2 = 48$ in.

After the rate of flow has been determined for one differential head, the rate of flow for any other differential head may also be easily determined by the following simple formula. Since the rate of flow varies directly with the square root of the differential head, the equation for this calculation is

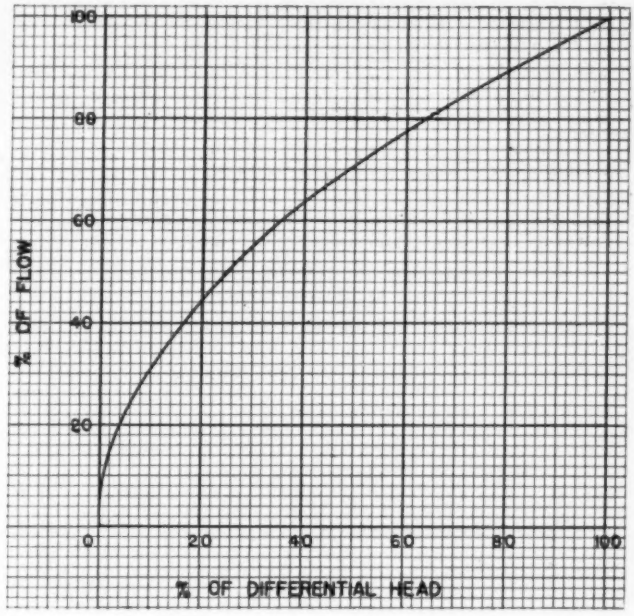

Fig. 3—Relation of Flow and Differential Head

$$Q_2 = Q_1\sqrt{\frac{h_2}{h_1}} \quad \text{——————} \quad \text{Eq.(11)}$$

If, with a differential head of 90 inches the rate of flow is found to be 1200 gpm., what will be the rate of flow with a differential head of 45 inches? (See Fig. 3)

Given, $h_1 = 90$ in., $Q_1 = 1200$, $h_2 = 45$ in. Desired - Q_2

By Eq. (11), $Q_2 = 1200\sqrt{\frac{45}{90}} = 848$ gpm.

The Manometer

The simplest method of determining the differential head produced by any differential producer is with the use of a U tube or manometer. Care should be exercised to be certain that all air has been expelled from the manometer before any measurements are made of the deflection of liquid level in the tubes.

The following equations apply to the manometer and its readings. The symbols involved are

H = Head of water in feet
h = Head of water in inches
d_f = Deflection of manometer liquid in inches
S = Specific gravity of manometer liquid.

$$h = d_f(s-1) \quad \text{——————} \quad \text{Eq.(12)}$$

$$H = \frac{h}{12} \quad \text{——————} \quad \text{Eq.(13)}$$

$$d_f = \frac{h}{(s-1)} \quad \text{——————} \quad \text{Eq.(14)}$$

$$s = \frac{h}{d_f} + 1 \quad \text{——————} \quad \text{Eq.(15)}$$

In addition to mercury, there are various liquids that may be used in manometer, all of which should be colored with an oil soluble dye, so that the point of division between the liquid being used and the water may be readily visible. Following are some of the liquids more commonly used.

Material	Gravity*
Carbon Tetrachloride	1.60
Acetylene Tetrabromide	2.95
Mercury	13.58

*Approximate Specific Gravity

When low rates of flow are encountered, requiring a liquid with a low specific gravity, so as to secure the maximum differential reading in the manometer tubes, carbon tetrachloride may be diluted with benzine to obtain any specific gravity from 1.60 down to 1.10. The specific gravity of the liquid being used

may be determined with a hydrometer, but such determination should always be made immediately *after* the liquid has been used. That value should be used in all calculations, because the specific gravity of the oils varies materially with temperature. The gravity of mercury need not be checked after taking differential readings and the gravity of 13.58 may be taken as a constant.

If possible, a liquid with a specific gravity that will produce a deflection of 12 inches or more should be used, because it is easily understood that an error of 1/16-in. in the measurement of a deflection, will result in a very much smaller error when the deflection is large than when it is relatively small.

Determining the Most Desirable Gravity for Manometer Liquids

If the approximate rate of flow is known, the approximate specific gravity required for any desired deflection may be determined as the following example indicates.

A 500 gpm. pump is to be tested.

Given - $d_1 = 8.21$, $d_1^2 = 67.404$, $d_2 = 5$ in., Assume $C = 0.61$

Desired - The specific gravity of manometer liquid that will produce a deflection of approx 16 in.

First it is necessary to determine the approx. h.

By Eq. (1), $R = \frac{8.21}{5} = 1.64$

From table III, $\sqrt{R^4 - 1} = 2.497$

By Eq. (6), $h = \left(\frac{500 \times 2.497}{5.667 \times 0.61 \times 67.404}\right)^2 = 28.7$ in.

By Eq. (15), $S = \frac{28.7}{16} + 1 = 2.79$

Since acetylene tetrabromide has a gravity (S) of 2.95 it it may be used straight and it will give a deflection of approx. 14.8 in. calculated as follows:

By Eq. (14), $d_f = \frac{28.7}{(2.95 - 1)} = 14.8$ in.

In case of high rates of flow which, upon pre-calculation as above, may cause the deflection of acetylene tetrabromide to exceed the capacity of the manometer, mercury should be used. For lower rates of flow, carbon tetrachloride diluted with benzine should be employed. With such a mixture of specific gravity 1.25, a deflection of 24 in. is secured from a differential through the orifice of only 6 inches of water head in accordance with Eq. (12)

$$h = 24(1.25 - 1.00) = 6 \text{ in.}$$

For the purpose of manufacturing design, academic research, or for the measurement of the flow of hot water or liquids with specific gravities and viscosities different from those of water, it is suggested that reference be made to "Fluid Meters, Their Theory and Application", (4th Edition) published by the American Society of Mechanical Engineers, and considered the outstanding compendium on the design and use of flow measuring equipment.

References

Fluid Meters, Theory and Application—A.S.M.E.
Handbook of Hydraulics—King—McGraw-Hill Book Co.
Cameron Hydraulic Data—Ingersoll-Rand Co.
Flow of Fluids—Crane Co.
Bulletin No. 22—Simplex Valve and Meter Co.
Bulletin No. 336—Builders Iron Foundry Co.
Instructions—Republic Flow Meter Co.
Instructions—The Brown Instrument Co.
Bulletin No. 301-A—The Bailey Meter Co.

Data Book for Civil Engineers

Elwyn E. Seelye, Consulting Engineer, has prepared a Data Book on Design for Civil Engineers. Unique in its presentation, the book is a compilation of data tablets, design sketches, notes, and references for design of structural units, (general, concrete, steel, wood, plywood, and foundations). There are also sections on soil, earthwork, roads, airports, bridges, dams, docks and piers.

Of particular interest to our readers are sections on drainage and sewerage, sewage treatment, waste disposal, water purification and water distribution. These latter sections comprise more than 125 pages, in which by means of pictures, diagrams, nomographs, charts, designs, tables, etc., the whole subject is covered from sewer manholes to Venturi meters. For the most part explanations and derivations have been eliminated since the notes on the plates give the required guidance and information. All the pages, which are large size (9¼ x 11½) contain cross-indexing. Many labor saving tables, modern codes and practice are used throughout the book.

In the section on water and sewage works are nomographs on pipe capacity, tables to be used for weir measurements, formulas, and graphs of the hydraulic elements of flow. Flow diagrams are shown for sewage treatment plants, along with sketches of various types of equipment, their location and their operation. Sizes of settling tanks, Imhoff tanks, dosing filters, trickling filters, activated sludge are all covered along with chlorinators, hypochlorinators, pumps, comminutors and sewage treatment for small systems.

Several pages are devoted to the analyses and tests to be made at sewage treatment laboratories, and another whole section is devoted to laboratory equipment recommended for sewage treatment plants. Waste disposal and incineration are likewise covered.

The section on water supply contains data, tables and formula on rainfall and runoff, storage, deep wells, distribution reservoirs, elevated storage tanks, pumping stations, weir measurement, Parshall flumes, etc., as well as drinking water requirements given in typical graphic tabular form for ready use and information.

Material on water purification covers slow and rapid sand filters, pressure filters, laboratory equipment, flow in pipes, water distribution, equivalent pipes, loss of head as well as information on cast iron pipe, cement-asbestos pipe, wood stave pipe, steel pipe, and various fittings.

This book, which is Volume 1 of a 3 volume series provides a concentrated collection of data helpful in the design and construction of practically all types of civil engineering structures. Published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., this book is listed at $7.50 per copy, and strikes us as being well worth the price. Prospective purchasers may determine the correctness of the statement during the period allowed by the publisher for free inspection and return. (G.E.S.)

A Manual for Water Plant Operators

According to the preface in the recently published *Manual For Water Plant Operators*, by A. A. Hirsch, the object of the manual is to provide a practical text for study by operators of water supply systems in preparation for certification examinations, and "a reference for their consultation in times of difficulty and doubt."

Divided into six sections: Supply procurement, methods of treatment, special treatments, distribution, control tests, and miscellaneous, the text covers all phases of water supply with which water works operators are concerned. Of particular help and usefulness are sections on pipe materials, hydraulic measuring devices, and plant arithmetic. A number of the equipment ideas are taken from the author's practical articles published in *Water Works & Sewerage*.

In the section on chemical tests, the principle involved is stated before the steps in the technic are given and this should be helpful to many operators. Other inclusions that will also be helpful to operators are such items as the explanatory diagrams of chlorinating equipment, a section on chlorination complaints, sections on trouble shooting, maintenance of pumps, maintenance of motors, and calculation of chemical dosages.

A chapter on Records and Operator Policy is something new in water works manuals and includes sections on daily records, diaries, monthly and annual reports. Even more unusual and valuable is a section on Public Relations and another on Operator Advancement, including discussions on self improvement, training programs and the benefits of membership in water works associations.

The author has striven for a method of presentation within the grasp of men without benefit of advanced schooling, and has followed a method of treatment intended to be intimate and definitive, rather than hazy or inconclusive.

A chapter on Useful Literature includes booklets, textbooks and periodicals, the former listed according to the phase of water supply with which they are concerned, (e.g. wells, plant, treatment, analysis, pumps, etc.). This reviewer objects to the listing of the Reference and Data Editions of *Water Works & Sewerage* in the "Plant" category alone because these volumes cover all phases of water supply.

The last chapter, devoted to "Useful Water Plant Data" contains a number of useful tables, and throughout the book are tables, and graphs, some of the latter of which have suffered by too great a reduction in size. Published by the Chemical Publishing Co., Dept. M. J., Brooklyn 2, N. Y., the *Manual For Water Plant Operators* contains 386 pages and retails for $6.50. (G.E.S.)

WATER WASTE SURVEYS AND LEAKAGE CORRECTION*

With Particular Reference to the Pitometer and Its Use in Making Such Surveys

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IT HAS been suggested that a pitometer survey be compared with a complete medical and physical examination such as would be made in a clinic. Various measurements would be made to determine the physical condition of the patient. The type of tests, the equipment and the technic have all been improved over the years, and, while these have probably resulted in better diagnosis, the basic tests have not been changed greatly. So it has been with the pitometer survey. Years ago the pitometer was called the x-ray of water works systems. Although new tools have been provided and technics improved to increase the efficiency of the survey, the basic flow measurements developed years ago are still important and valuable.

To carry the medical analogy one step further, let us consider that the counterpart of the general practitioner or family doctor is the water works superintendent or local engineer. While these men do splendid work and in some cases operate for years without any outside help or advice, it is quite common for a progressive doctor to send a patient to a clinic for a complete physical and medical examination. At the clinic are to be found doctors trained in this type of work—men who specialize in a particular field and for this reason excel in it. The need for an organization of engineers which specializes in conducting pitometer surveys and can be called on at any time to help in whatever way is desired, whether it be for a short test or a complete survey, is somewhat similar to the need for clinics. Perhaps this need is best illustrated by the fact that during the last five years, the author's firm has conducted a total of 251 surveys and tests in 159 different communities. The majority of these were water waste surveys that covered approximately 12,000 mi. of mains. This work resulted in the location and repair of over 6,500 hidden underground leaks wasting a total of 106 mgd. At an average purchase or production cost of five cents per 1,000 gal., this amount of water represents an annual saving of $1,935,000.

While the judgment of federal agencies is not necessarily the best criterion, it is interesting to note that the 251 surveys and tests included work for four large Navy shipyards, as well as for several cities where the FWA thought it sound practice to have a survey made before approving grants for expensive extensions and reinforcements. The federal government of one of our neighboring countries also authorized a pitometer survey in one of its cities, as the quickest and most economical means of obtaining an adequate supply for one of its largest arsenals. Also included are tests for important war plants, including a government arsenal, airplane manufacturing plants and oil refineries.

Scope of Pitometer Surveys

The pitometer survey is an engineering operation divided into two definite fields:

1. An accounting for all the water delivered to the distribution system, known as the water waste survey.
2. An engineering study of the existing distribution system to improve distribution facilities.

While the primary object of the pitometer water waste survey is to locate underground leakage, its scope is very much broader than this. The operations may be divided as follows:

1. Test of pumps for slip or efficiency.
2. Measurement of the flows at either end of gravity supply lines to determine leakage.
3. Measurement of the flow in and out of reservoirs to determine leakage.
4. Test of master meters for accuracy.
5. Measurement of the flow to various districts of the city. A study of the night rate of flow and its relation to the total, indicates the existence of leakage. Also, the information obtained is the basis for future design and extensions and replacements in a distribution system.
6. A test of large industrial meters and a check on industries for unauthorized use of water.
7. Night subdivision, or the analysis of the night rate of flow in districts where waste is indicated, which result in the measurement of the flow in every block or between every set of valves.
8. Location of underground leakage. By this method of night subdivision, every underground leak in the system large enough to justify the cost of repair is indicated by measurement and its exact location determined by the use of sound intensifiers.
9. House-to-house inspections, based on the result of night subdivision, are carried out for the purpose of controlling leaking plumbing fixtures in unmetered systems. In metered systems, the measurements provide indications of under-registration of domestic meters.
10. Special tests that include such things as river-crossing tests, industrial tests and measurements not mentioned above.

Not all surveys result in spectacular findings in each of these steps but the following examples are not unusual, and some of them have been encountered in otherwise well-operated systems.

Pump Tests

The logical starting point of any engineering project of this kind is the source of supply. In the early days where the supply was pumped, a test to determine the slip of the reciprocating pumps frequently showed amazing conditions. In some cases where maintenance was entirely absent, slip ran as high as 80 to 90 per cent, as could be demonstrated by shutting the discharge valves practically to the closed position without raising the discharge pressure.

As reciprocating pumps have been replaced by centrifugal pumps, the pump tests have come to include wire-to-water efficiency tests. These, too, sometimes show surprising conditions, as described in an excellent paper by H. E. Beckwith, entitled, "A Simple Method of Testing Centrifugal Pumps" (*Jour. A.W.W.A.*, 31: 2098 (1939)). According to Beckwith, it is not unusual to find a centrifugal pump which is operating under an entirely different set of conditions than that for which it was designed. He cites a test that gave a wire-to-water efficiency of only 40 per cent. The savings resulting from the installation of a pump designed to meet the operating conditions were very substantial.

Supply Lines

In gravity systems, the starting point for the survey is the reservoir and the gravity supply lines it feeds. A test of the gravity supply lines is made by measuring the flow at the inlet and at the outlet and, at the same time, leakage from the reservoir is determined by measuring the rise and fall in the reservoir, adjusted for the flow in or out, as the case may be. Where a long gravity supply line crosses rough and marshy country and possibly a river, it is important to know by direct measurement that there is no appreciable underground leakage.

The approximation of accuracy by any hydraulic instrument in the field is not much greater than 100 ± 2 per cent. In large gravity lines, a small loss could go undetected, due to the allowable error of the measurements. At the same time it should be pointed out that many losses have been detected where the difference between the inlet and outlet quantities did not exceed 3 to 4 per cent. In a survey for a small New Jersey system, a measurement of the flow in each end of a gravity line, 7 mi. long, showed discrepancies of 30 per cent between the reservoir and the town. The demands of this system had gradually increased over a period of years until it became necessary to install a booster pump in order to maintain an adequate supply. After the original discrepancy had been detected, intermediate gagings were made to localize the section where the loss occurred. Sound intensifiers were then used with positive assurance that leakage existed and a blown joint, which was wasting 250,000 gpd. into a large swamp, was quickly discovered.

Master Meter Tests

The testing of master meters for accuracy is a routine step that is necessary if figures on unaccounted-for water are to be used as the criterion for efficient operation and the absence of lost water. In the case where water is purchased through a master meter this test has a real dollar value and in two New Jersey communities substantial savings resulted from the discovery that the meters were over-registering. In one case there was an overcharge of 16 per cent. In the other instance, it was

*From the *Jour. AWWA*, 37, 181-188 (1945).

found that the flow through the master meters reversed during the night hours. Because the type of meter used registered positively, regardless of the direction of flow, this community was charged twice for water that was never used—once when it entered the system and again when it left it.

District Measurements

The division of a system into districts and the measurement of the flow into each district for a period of at least 24 hours provides information that is not only of value in indicating the existence of underground leakage, but gives valuable information regarding the operation of the entire distribution system. Primarily the district measurements are made so that the night rates of flow may be studied. The actual size of the district will vary but usually includes from 8 to 10 mi. of main and may be as large as 30 mi. A high flow at night of over 30 per cent of the total in the residential section of a metered system indicates the possibility of leakage and justifies further investigations, while a 40 per cent night rate is a sure indication of leakage or waste of some kind. A low ratio of night flow to the total flow, however, indicates that it would be uneconomical to make further investigations.

In cities where more than one survey has been made, a comparison with results of the previous district measurements provides a more exact means for predicting the existence of leakage. Some of our larger cities, notably Philadelphia, Pittsburgh, Rochester, Boston and Cincinnati, have found it economical to have a certain amount of work done each year, so as to keep their waste down to a minimum.

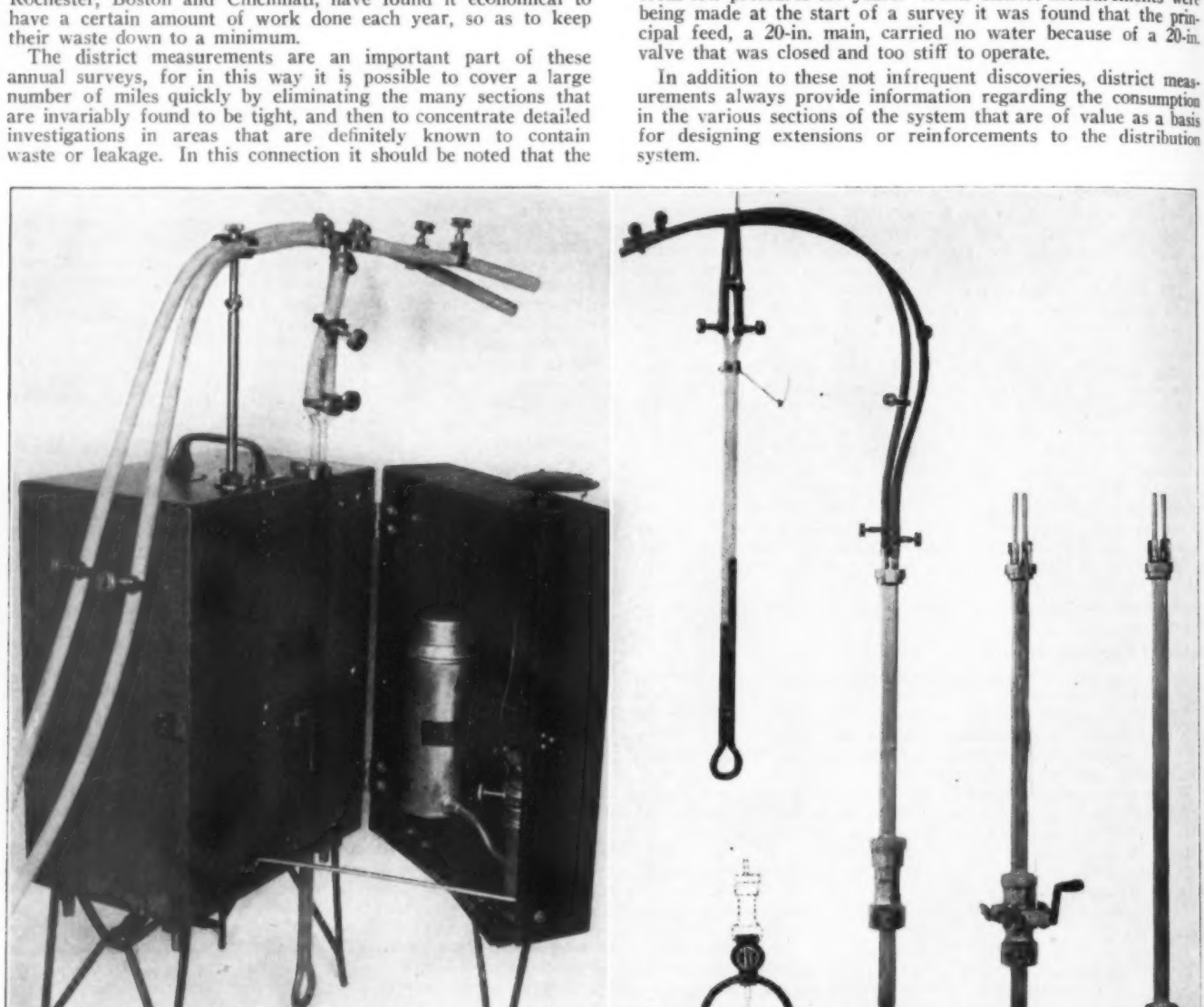
The district measurements are an important part of these annual surveys, for in this way it is possible to cover a large number of miles quickly by eliminating the many sections that are invariably found to be tight, and then to concentrate detailed investigations in areas that are definitely known to contain waste or leakage. In this connection it should be noted that the over-all accounted-for figures in large systems, where the consumption may be 30 to 40 mgd. or greater, are subject to so many variables with regard to consumption that it is not as easy to detect the presence of underground leakage as it is in a small compact system. A change of only a small percentage in a large system can involve more water than the entire consumption of the small system.

By isolating the districts by means of closed valves, so that the feed may be supplied through one or more large mains on which the pitometer is installed, it is possible to learn a good deal about the operation of the trunk mains. Pressures are taken before and after the district is isolated. The flows are studied and the adequacy of existing feeds taken into consideration, so that in case of fire there will be ample supply until the key boundary valves are opened in accordance with arrangements made between the fire and the water departments.

In one survey the formation of the district boundaries proved to be a difficult operation, due primarily to the condition of the valves and errors in the map. The time involved in solving the problem, however, proved to be well worth-while for the city because two of its important feeders were found to be carrying no water. Investigation showed that one 12-in. valve was closed, one double-check valve was frozen closed and one 12-in. valve was partly closed. The latter discovery explained the reason for inadequate pressures during a recent fire.

In another system there was a high area that had suffered from low pressures for years. When district measurements were being made at the start of a survey it was found that the principal feed, a 20-in. main, carried no water because of a 20-in. valve that was closed and too stiff to operate.

In addition to these not infrequent discoveries, district measurements always provide information regarding the consumption in the various sections of the system that are of value as a basis for designing extensions or reinforcements to the distribution system.



Equipment Used in Pitometer Survey

Photo Recorder

Pitometer Rods and Monometer

Industrial Meter Tests

Improved meter practice and close supervision of industrial consumers has greatly reduced the loss of water in many systems, but there are still a large number of meter departments which do not make complete checks on the accuracy of the large meters and the use of water passing through them and through fire lines.

The advantages of testing large meters in place and under operating conditions, with the pitometer, may not be apparent to those meter superintendents who periodically use a test meter to check their meters. While it is true that there are some systems where the meters are in excellent condition, within three weeks two cases of under-registration involving large quantities of water were brought to light during routine field tests. In one large eastern city, a fire line meter was tested in spite of the fact that it showed no registration and that the factory said they were not using any water through it. The test showed that there not only was a flow but it was so large that a continuous test was run for a week. The average under-registration for this period was 427,000 gpd. and the rate varied from zero to maximum of 1,660,000 gpd. through a 6-in. pipe, or a velocity of over 13 fps. Four hundred and twenty-seven thousand gallons per day is not only a lot of lost water, but at a meter rate of ten cents per 1,000 gal. the lost revenue amounts to over $15,000 a year.

Night Subdivision and Leak Location

Following the 24-hour district measurement comes the problem of locating all underground leakage. Indirect gaugings are made to determine the distribution of the night rate of flow. These gaugings are made after midnight and before five o'clock in the morning. All mains, regardless of how small they may be, are included in these measurements and the unit of test is as small as it is practicable to make it with the valves available. Manifestly, if there is no flow into a piece of pipe after midnight there can be no leakage. Where an appreciable flow is shown to exist, further investigations are made to determine the cause. The importance of these measurements cannot be over-emphasized, because only in this way is there a *positive* indication of the existence of underground leakage.

The location of leaks has been a common occurrence in every water works since the first leak patrols were organized in England over 100 years ago and perhaps long before that. The main point to be emphasized here is the difference between the leak patrol or listening type of survey and the pitometer survey. By the periodic use of sound intensifiers leakage can be and is controlled by almost every water works plant. This type of control is excellent practice and should be encouraged. At the same time it should be recognized that this method is in a sense a negative control, *i.e.*, if no noise is heard on a main or its connections, it is concluded that there is no leakage; or if a slight noise is heard, and further investigation does not result in the discovery of a leak, it is concluded that the leak is too small to bother with, which may not be the case. Experience indicates that the intensity of sound does not necessarily indicate the volume or size of a leak.

An actual measurement of the flow between a set of valves when use is at a minimum, or is a known quantity, is a *positive* approach. Only after a water measurement is made can it positively be said that leakage does or does not exist, and, if there is leakage, only by a water measurement can the amount be determined. In the pitometer survey it is at this point that sound intensifiers are first used. Then with a definite knowledge of the size and approximate location of the loss, investigations are made with whatever type intensifier the engineer prefers, until all leakage of sufficient importance to warrant repair is located.

The record is full of instances where the sound indications were so misleading or faint that large leaks had existed for years. Take, for example, interfering noises from pumps, motors, regulating valves, machinery, etc., or the case of a deep fill, a river-crossing or an abandoned service.

In this connection it is worth noting that the quantity of leakage located, rather than the number of leaks, is the important consideration to a community. For example, a survey was made in a metered New England city having a domestic per capita consumption to 64 gpd. Only a handful of small service leaks were found in the distribution system proper, but because the survey was a complete audit, a measurement was made on a pumping line leading to a reservoir some distance out of the city. This main crossed some rough and swampy ground and there were no connections to it. The function of the pump station was to augment the main gravity supply to the reservoir and whenever the water level dropped to a certain point the pump started and ran until the reservoir was filled. The measurement on this main showed a loss between the pump station and reservoir of 430,000 gpd. and further investigation resulted in the discovery of a leak wasting 250,000 gpd. into the swamp, when the pump was off, and 390,000 gpd. when it was operating and the pressure thus increased. This one leak was largely responsible for the need of pumping, as it was continuously draining the reservoir. The savings in pumping costs alone amounted to $4.50 per day at one cent per kilowatt hour.

At the other extreme, is the case of a large unmetered gravity system where leakage and waste were rampant because there was an abundant supply. Unfortunately, the capacity of the 7-mi. transmission mains was limited and shortly before the war the demand had increased to the point where pressure troubles developed and it was necessary to curtail service in order to get water into the large distribution reservoir. Then with the war came a large arsenal that demanded 10 per cent of the total consumption. This additional amount could not be supplied and so the government authorized a complete pitometer survey as the quickest and most economical approach to obtaining an additional supply. Here the resultant action could be called selective leak location. Only the large leaks were dug up and repaired at first so as to reduce consumption as rapidly as possible, and in this case measurements were invaluable. Hydrant leaks making a terrific roar were encountered on almost every other corner, and yet broken mains, part of the time submerged by the tidal river, made no noise at all on the surface of the street due to the nature of the ground conditions and undermined pavements. Within six weeks, leaks releasing over 4 mgd. had been repaired and at the completion of the survey leaks totaling 13 mgd. had been located.

Other Benefits of Subdivision Studies

In addition to providing positive information regarding leakage, the night subdivision measurements have several other valuable features. During the course of the measurements, it is necessary to close a large majority of the valves in the distribution system and prove their condition by making tight shut-outs. Periodic inspections and operation of all valves in a distribution system is generally considered good practice. Usually, however, shut-outs are not made during the inspection, the main object being to see that the valve is free and in good condition. When a survey is made the night valve operations can take the place of the annual inspections. Many systems do not follow a valve maintenance program at all and in these cases the operations made during the survey are useful, not only as a check on the condition of the valves, but also on the distribution system map and records. One of the most interesting discoveries resulting from valve operations occurred in a southern city where it was found that a great many of the mains were not connected at intersections. This, it was said, came about as a result of street grading after part of the system had been installed, thus increasing the cover. When the gridiron was completed, no effort was made to connect mains that were at different depths. Only by methodically proving how the water was circulating were all these missing connections located, and the improvements in the strength of the distribution system after connections were made can be readily appreciated.

House Waste

The only sure way to eliminate unnecessary waste on the consumer's property is by universal metering. There are, however, many communities where universal metering is impractical for financial or political reasons, and in these communities only the largest consumers are metered.

The only other method of controlling this waste is by periodic house-to-house inspections and these are most efficiently supervised when the amount of water being wasted is first determined by night measurements. Following these, concentrated work in those sections found to have a large night consumption will produce the best results.

The benefits from these inspections are only temporary unless repeated at regular intervals and even then have no control over willful waste. However, a pitometer survey will indicate the most wasteful sections and several cities have adopted ordinances authorizing the water department to install meters when reinspections show that the consumer is a chronic waster of water and will not keep his fixtures in repair.

Distribution Studies

A second type of survey, the distribution study, has an objective somewhat different from the waste survey. Basic data accumulated through loss-of-head tests, fire flow tests, pressure and hydraulic grade line studies and computations are all dependent on a variety of flow measurements and gagings. The pitometer distribution survey is of value in determining the true physical condition of a distribution system before designing improvements.

Whether the problem be the location of points of waste or the proper method of extending or improving the distribution system, the pitometer survey will be found to be a most valuable method of finding the proper solution.

U. S. DRINKING WATER STANDARDS

THE U. S. Public Health Service, under its authority, has issued four successive standards of quality for water used on interstate carriers. These documents were released in 1914, 1925, 1942 and 1946. The 1946 standards are published hereinafter. . . .

It will be understood that the A.W.W.A has no authority to promulgate or enforce a standard of quality for public water supplies. It can, however, for its membership, voluntarily accept such standards for application to water supplies under the control of its members, and thus by implication make them professional standards commanding the broad and general acceptance to which such documents are entitled.

The Board of Directors of the A.W.W.A., therefore, after careful consideration and deliberation, on Jan. 14, 1946, adopted the following resolution:

WHEREAS, The Officers and Directors of the American Water Works Association are desirous of supporting all efforts to promote better health through safe water supplies, and

WHEREAS, It is noted that the Standards of the U.S.P.H.S. are promulgated by the Surgeon General for use in the administration of Interstate Quarantine Regulations, and that they are intended to apply only to water used on common carriers engaged in interstate commerce, and

WHEREAS, It does not appear that the Surgeon General desires or proposes to extend the authority of the U.S.P.H.S. to include any water supplies other than those used by common carriers subject to Federal Quarantine Regulations, and

WHEREAS, It is the desire of the A.W.W.A. to have available for reference, to recognize and to accept fair and effective standards for quality of water furnished by all public water supply systems, and

WHEREAS, The Officers and Directors of the A.W.W.A. have studied the text of the proposed 1946 Drinking Water Standards which have been developed by the Surgeon General of the U.S.P.H.S. and found the terms and conditions of these Standards to be constructive, and

WHEREAS, It is the earnest hope of the A.W.W.A. that, as a result of its voluntary acceptance of the Drinking Water Standards as criteria of quality of all public water supplies in the United States, the state boards of health and their sanitary engineering personnel will find it possible to further constructive and co-operative relationships with the water works management to the ends that deficiencies in water supply systems be corrected as promptly as feasible; that extraneous sources of contamination of water be eliminated; and that encouragement be given to training and employment of qualified personnel in positions of responsibility in the operation of water works,

NOW THEREFORE BE IT RESOLVED by the Officers and Directors, acting for the American Water Works Association, that the 1946 Drinking Water Standards proposed for adoption by the U.S.P.H.S. be voluntarily accepted by our Association as the standards for all public water supplies.

Jour. A.W.W.A., March, 1946.

U. S. Public Health Service Standards

1. Definition of Terms

For the purpose of these Standards the terms designated herein below shall be defined as follows:

1.1. *Adequate protection by natural agencies* implies various relative degrees of protection against the effects of pollution in surface waters; dilution, storage, sedimentation, the effects of sunlight and aeration and the associated physical and biological processes which tend to produce natural purification; and, in the case of ground waters, storage in and percolation through the water-bearing material.

1.2. *Artificial treatment* includes the various processes commonly used in water treatment, both separately and in combination, such as storage, aeration, sedimentation, coagulation, rapid or slow sand filtration, chlorination and other accepted forms of disinfection. Rapid sand filtration treatment is commonly understood to include those auxiliary measures, notably coagulation and sedimentation, which are essential to its proper operation.

1.3. *Adequate protection by artificial treatment* implies that the method and degree of elaboration of treatment are appropriate to the source of supply; that the works are of adequate capacity to support maximum demands, are well located, designed and constructed, are carefully and skillfully operated and supervised by properly trained and qualified personnel, and are adequately protected against floods and other sources of pollution. The evidence that the protection thus afforded is adequate must be furnished by frequent bacteriological examinations and other appropriate analyses showing that the purified water is of good and reasonably uniform quality, a recognized principle being that irregularity in quality is an indication of potential danger. A minimum specification of good quality would be conformance to the bacteriological and chemical requirements of these Standards, as indicated in Sections 3 and 4.

1.4. *Sanitary defect* means any faulty structural condition, whether of location, design or construction of collection, treatment or distribution works which may regularly or occasionally prevent satisfactory purification of the water supply or cause it to be contaminated from extraneous sources. Among the extraneous sources of contamination of water supply are dual supplies, bypasses, cross-connections, interconnections and back-flow connections.

1.5. *Health hazard* means any faulty operating condition, including any device or water treatment practice, which, when introduced into the water supply system, creates or may create a danger to the well-being of the consumer.

1.6. *Water supply system* includes the works and auxiliaries for collection, treatment and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.

1.7. *The coliform group of bacteria* is defined, for the purpose of these Standards, as including all organisms considered in the coli-aerogenes group as set forth in the *Standard Methods for the Examination of Water and Sewage*, current edition, prepared, approved and published jointly by the American Public Health Association and the American Water Works Association, New York City. The procedures[1] for the demonstration of bacteria of this group shall be those specified herein, for:

(*a*) The completed test, or

(*b*) The confirmed test when the liquid confirmatory medium brilliant green bile lactose broth, 2 per cent, is used, providing the formation of gas in any amount in this medium during 48 hours of incubation at 37°C. is considered to constitute a positive confirmed test, or

(*c*) The confirmed test when one of the following liquid confirmatory media is used: crystal violet lactose broth, fuchsin lactose broth or formate ricinoleate broth. For the purpose of this test, all are equivalent, but it is recommended that the laboratory worker base his selection of any one of these confirmatory media upon correlation of the confirmed results thus obtained with a series of completed tests, and that he select for use the liquid confirmatory medium yielding results most nearly agreeing with the results of the completed test. The incubation period for the selected liquid confirmatory medium shall be 48 hours at 37°C. and the formation of gas in any amount during this time shall be considered to constitute a positive confirmed test.

1.8. *The standard portion of water* for the application of the bacteriological test may be either:

(*a*) Ten milliliters (10 ml.) or

(*b*) One hundred milliliters (100 ml.)

1.9. *The standard sample* for the bacteriological test shall consist of five (5) standard portions of either:

(*a*) Ten milliliters (10 ml.) or

(b) One hundred milliliters (100 ml.) each.

In any disinfected supply the sample must be freed of any disinfecting agent within twenty (20) minutes of the time of its collection.[2]

1.10. *The certifying authority* is the Surgeon General of the United States Public Health Service or his duly authorized and designated representatives. Reference to the certifying authority shall be applicable only in the cases of those water supplies to be certified for use on carriers subject to the Federal Quarantine Regulations.

The reporting agency shall be understood to mean the respective official state health agencies or their designated representatives.

[1] This reference shall apply to all details of technique in the bacteriological examination, including the selection and preparation of apparatus and media, the collection and handling of samples, and the intervals and conditions of storage allowable between collection and examination of the water sample.

[2] In freeing samples of chlorine or chloramines, the procedure given in the *Standard Methods for the Examination of Water and Sewage*, current edition, shall be followed.

2. As to Source and Protection

2.1. The water supply shall be:

(a) Obtained from a source free from pollution; or

(b) Obtained from a source adequately purified by natural agencies; or

(c) Adequately protected by artificial treatment.

2.2. The water supply system in all its parts should be free from sanitary defects and health hazards, and all known sanitary defects and health hazards shall be systematically removed at a rate satisfactory to the reporting agency and to the certifying authority. Approval of public water supplies by the reporting agency and the certifying authority will be conditioned by the existence of:

(a) Rules and regulations prohibiting connections or arrangements by which liquids or chemicals of unsafe, unknown or questionable quality may be discharged or drawn into the public water supply;

(b) Provisions to enforce such rules and regulations effectively on all new installations; and

(c) A continuing program to detect health hazards and sanitary defects within the water distribution system.

2.21. *Applications*—For the purposes of these standards, responsibility for conditions in the water supply systems shall be considered to be held by:

(a) The water purveyor from the source of supply to the connection to the customer's service piping, and

(b) The owner of the property served and the municipal, county or other authority having legal jurisdiction from the point of connection to the customer's service piping to the free-flowing outlet of the ultimate consumer.

3. As to Bacteriological Quality

3.1. *Sampling*—The bacteriological examination of water considered under this section shall be of samples collected at representative points throughout the distribution system.

The frequency of sampling and the location of sampling points on the distribution system should be such as to determine properly the bacteriological quality of the water supply. The frequency of sampling and the distribution of sampling points shall be regulated jointly by the reporting agency and the certifying authority after investigation by either agency, or both, of the source, method of treatment and protection of the water concerned.

The minimum number of samples to be collected from the distribution system and examined by the reporting agency or its designated representatives each month should be in accordance with the number as determined from the graph presented in Fig. 1 of these Standards[3] which is based upon the relationship of population served and minimum number of samples per month:

[3]For the purpose of uniformity and simplicity in application, the number of samples to be examined each month for any given population served shall be determined from the graph in accordance with the following:

For populations of 25,000 and under to the nearest 1

For populations of 25,001 to 100,000 to the nearest 5

For populations of 100,001 to 2,000,000 to the nearest 10

For populations of over 2,000,000 to the nearest 25.

Population served	Min. no. of samples per mo.
2,500 and under	1
10,000	7
25,000	25
100,000	100
1,000,000	300
2,000,000	390
5,000,000	500

In determining the number of samples examined monthly, the following samples may be included, provided all results are assembled and available for inspection and the laboratory methods and technical competence of the personnel are approved by the reporting and certifying agencies:

(a) Samples examined by the reporting agency.

(b) Samples examined by local health department laboratories.

(c) Samples examined by the water works authority.

(d) Samples examined by commercial laboratories.

Daily samples collected following an unsatisfactory sample as provided in Sections 3.22 and 3.24 shall be considered as special samples and shall not be included in the determination of the number of samples examined monthly. Neither shall subsequent unsatisfactory samples in this daily series be used as a basis for prohibiting the supply, provided that (1) immediate and active efforts are made to locate the cause of such contamination, (2) immediate action is taken to eliminate such cause, and (3) samples taken following such remedial action are satisfactory.

The laboratories in which these examinations are made and the methods used in making them shall be subject to inspection at any time by the designated representatives of the certifying authority and reporting agency. Compliance with the specified procedures and the results obtained shall be used as a basis for certification, in accordance with the application given below.

3.2. *Application*—Applications 3.21 and 3.22 given below shall govern when ten-milliliter (10-ml.) portions are used and applications 3.23 and 3.24 shall govern when one hundred-milliliter (100-ml.) portions are used.[4]

3.21. Of all the standard ten-milliliter (10-ml.) portions examined per month in accordance with the specified procedure, not more than ten (10) per cent shall show the presence of organisms of the coliform group.

3.22. Occasionally three (3) or more of the five (5) equalling ten-milliliter (10-ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:

(a) Five (5) per cent of the standard samples when twenty (20) or more samples have been examined per month.

(b) One (1) standard sample when less than twenty (20) samples have been examined per month.

Provided further that when three or more of the five equalling ten-milliliter (10-ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.[5]

3.23. Of all the standard one hundred-milliliter (100-ml.) portions examined per month in accordance with the specified procedure, not more than sixty (60) per cent shall show the presence of organisms of the coliform group.

3.24. Occasionally all of the five (5) equalling one hundred-milliliter (100-ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:

(a) Twenty (20) per cent of the standard samples when five (5) or more samples have been examined per month.

(b) One (1) standard sample when less than five (5) samples have been examined per month.

Provided further that when all five of the standard one hundred-milliliter (100-ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.[6]

3.25. The procedure given, using a standard sample composed of five standard portions, provides for an estimation of the most probable number of coliform bacteria present in the sample as set forth in the following tabulations:

No. of portions		M.P.N. of coliform bacteria per 100 ml.	
Negative	Positive	When 5-10-ml. portions are examined	When 5-100-ml. portions are examined
5	0	Less than 2.2	Less than 0.22
4	1	2.2	.22
3	2	5.1	.51
2	3	9.2	.92
1	4	16.0	1.60
0	5	More than 16.0	More than 1.60

4. As to the Physical and Chemical Characteristics

4.1. *Physical characteristics*[7]—The turbidity of the water shall not exceed 10 ppm. (silica scale), nor shall the color exceed 20 (standard cobalt scale). The water shall have no objectionable taste or odor.

4.2. *Chemical characteristics*—The water shall not contain an excessive amount of soluble mineral substance, nor excessive amounts of any chemicals employed in treatment. Under ordinary circumstances, the analytical evidence that the water satisfies the physical and chemical standards given in Sections 4.1 and 4.21 and simple evidence that it is acceptable for taste and odor will be sufficient for certification with respect to physical and chemical characteristics.

4.21. The presence of lead (Pb) in excess of 0.1 ppm., of fluoride in excess of 1.5 ppm., of arsenic in excess of 0.05 ppm., of selenium in excess of 0.05 ppm., of hexavalent chromium in excess of 0.05 ppm., shall constitute grounds for rejection of the supply.

These limits are given in parts per million by weight and a reference to the method of analysis recommended for each determination is given in Section 4.31. Salts of barium, hexavalent chromium, heavy metal glucosides or other substances with deleterious physiological effects shall not be added to the system for water treatment purposes.

Ordinarily analysis for these substances

[4]It is to be understood that in the examination of any water supply the series of samples for any one month must conform to both of the above requirements, either 3.21 and 3.22 or 3.23 and 3.24, respectively.

[5]When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 10 ml. to 0.1 ml. or less.

[6]When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 100 ml. to 1.0 ml. or less.

[7]The requirements in Section 4.1 relating to turbidity and color shall be met by all filtered water supplies. Turbidity and color limits for unfiltered waters and the requirements of freedom from taste or odor for either filtered or unfiltered waters should be based on reasonable judgment and discretion, giving due consideration to all the local factors involved.

need be made only semi-annually. If, however, there is some presumption of unfitness because of these elements periodic determination for the element in question should be made more frequently.

Where experience, examination and available evidence indicate that such substances are not present or likely to be present in the water supplies involved, semi-annual examinations are not necessary, provided such omission is acceptable to the reporting agency and the certifying authority.

4.22. The following chemical substances which may be present in natural or treated waters should preferably not occur in excess of the following concentrations where other more suitable supplies are available in the judgment of the certifying authority. Recommended methods of analysis are given in Section 4.3.

Copper (Cu) should not exceed 3.0 ppm.

Iron (Fe) and manganese (Mn) together should not exceed 0.3 ppm.

Magnesium (Mg) should not exceed 125 ppm.

Zinc (Zn) should not exceed 15 ppm.

Chloride (Cl) should not exceed 250 ppm.

Sulfate (SO_4) should not exceed 250 ppm.

Phenolic compounds should not exceed 0.001 ppm. in terms of phenol.

Total solids should not exceed 500 ppm. for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 ppm. may be permitted.

For chemically treated waters, i.e., lime-softened, zeolite or other ion-exchange treated waters, or any other chemical treatments, the following three requirements should be met:

(1) The phenolphthalein alkalinity (calculated as $CaCO_3$) should not be greater than 15 ppm. plus 0.4 times the total alkalinity. This requirement limits the permissible pH to about 10.6 at 25° C.

(2) The normal carbonate alkalinity should not exceed 120 ppm. Since the normal alkalinity is a function of the hydrogen-ion concentration and the total alkalinity, this requirement may be met by keeping the total alkalinity within the limits suggested below when the pH of the water is within the range given. These values apply to water at 25° C.

pH Range	Limit for total alkalinity (ppm. as $CaCO_3$)
8.0 to 9.6	400
9.7	340
9.8	300
9.9	260
10.0	230
10.1	210
10.2	190
10.3	180
10.4	170
10.5 to 10.6	160

(3) If excess alkalinity is produced by chemical treatment, the total alkalinity should not exceed the hardness by more than 35 ppm. (Calculated as $CaCO_3$).

4.3 Recommended methods of analysis[8]:

4.31. Ions with required limits of concentration.

[8]For the chemical determinations referred to in this report, when given, the methods of analysis recommended by the Association of Official Agricultural Chemists are satisfactory and may be substituted for those recommended in the *Standard Methods for the Examination of Water and Sewage*, current edition, which are specifically cited.

Arsenic (As): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, p. 390; also "Colorimetric Microdetermination of Arsenic," Morris B. Jacobs and Jack Nagler. *Industrial and Engineering Chemistry*, Anal. Ed., **14**: 442 (1942).

Fluoride (F): *Standard Methods for the Examination of Water and Sewage*, current edition; also "Methods of Determining Fluorides," Committee Report, A. P. Black, Chairman. *Journal American Water Works Association*, **33**: 1965-2017 (1941).

Lead (Pb): *Standard Methods for the Examination of Water and Sewage*, current edition.

Selenium (Se): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, pp. 11 and 417; also Robinson, W. O., Dudley, H. C., Williams, K. T., and Byers, Horace G.: "The Determination of Selenium and Arsenic by Distillation." *Industrial and Engineering Chemistry*, Anal. Ed., **6**: 274 (1934).

Hexavalent Chromium: *Standard Methods for the Examination of Water and Sewage*, current edition.

4.32. Ions and substances with suggested limits of concentration.

Copper (Cu): *Standard Methods for the Examination of Water and Sewage*, current edition.

Iron (Fe) and Manganese (Mn): Ibid.

Magnesium (Mg): Ibid.

Zinc (Zn): Ibid.

Chloride (Cl): Ibid.

Sulfate (SO_4): Ibid.

Phenolic compounds: Ibid. With dibromquinonechlorimide as an indicator.

Total solids: Ibid.

Alkalinity: Ibid.

Bacterial Properties of Chloramines

In the Feb. 8, 1946 issue of the *U. S. Public Health Reports*, Vol. 61, pp. 157-192, appears a report on a study of the "Bacterial Properties of Chloramines," written by the investigators, C. T. Butterfield, Prin. Bacteriologist, and Elsie Wattie, Bacteriologist, U. S. Public Health Service, Sanitary Engineering Division, Water and Sanitation Investigation, Cincinnati, Ohio.

A previous paper had investigated the influence of pH and temperature on the survival of coliforms and enteric pathogens when exposed to free chlorine. The work in this recent study investigates the effect of chlorine compounds on bacteria, particularly the chloramines as would exist in a chlorinated water which had not been chlorinated to the breakpoint.

The most pertinent findings of the study may be taken from the summary of the article.

1. The length of time of exposure of the bacteria in water to chloramine and the amount of chloramine present are primary factors governing the rate of bacterial kills. Under favorable conditions (pH 7.0; 20 to 25 °C.) 100 per cent kills cannot be expected in less than 20 minutes with chloramine residuals of about 1.2 ppm.

2. The hydrogen-ion concentration has a pronounced effect on bacterial activity of chloramine, the activity being diminished with each decrease in hydrogen-ion concentration, i.e. increase in pH value.

3. A lowering of temperature retards the bacterial activity of chloramine.

4. Under certain conditions some strains of certain enteric bacteria appear more resistant than are E. Coli.

5. The presence of excessive amounts of ammonia nitrogen (Cl_2: N ratios up to 1:25) did not markedly reduce the bactericidal efficiency of the resultant chloramines.

6. The duration of the contact time (0 to 68 hr.) of the chloramine components, chlorine and ammonia, did not alter the bactericidal properties of the chloramine.

7. Chloramines are much less efficient as bactericidal agents than free chlorine. Thus to obtain a 100 per cent kill with the same period of exposure required about 25 times more chloramine chlorine than chlorine as such, and to obtain the same kill with the same amounts of chlorine as chloramine under the same conditions required approximately 100 times the exposure period for the chloramine.

A First Annual Report Alliance, O.

It is not uncommon for annual reports to be issued as much as six months or more after completion of the year covered. We consider it rather unique, therefore, that the First Annual Report of the Dept. of Water and Sewage of Alliance, O., was issued within a month after the end of 1945. Prepared by Donald D. Heffelfinger, Engineer-Manager, this report is complete from the growth of population curve from 1875 to 1945, cost of sewage treatment plant contracts, present and proposed, as listed on the final page 38 of the report.

Mr. Heffelfinger has included in this outstanding mimeographed annual report property maps of the Dept. of Water and Sewage, flow diagrams of the management, as well as flow diagrams of the physical properties, both for water and for sewage plants, map of proposed water supply, and charts showing receipts and expenses from 1938 to '45.

One of the interesting items included in the report is the appraisal of the water department at $1,940,000, and the appraisal of the sewage works at $841,200. This does not include the 60 miles of sanitary sewers in the city. Water rates run from a minimum of $3.25 for 8,000 gallons to 19 cents per 1000 gal. for the next 42,000 gallons, and 12 cents per 1000 for the next 50,000 gallons. Discounts of 10 per cent are allowed if bills are paid by the 10th of the month. Sewer rates, also quarterly, are 25 cents per month for each water connection installed within the city, plus an additional charge of 5 per cent of the cost of water consumed over the minimum charge of $3.25 per quarter, with a maximum charge of $200. Outside the city the charge is $2.00 per quarter for domestic, and $1.00 per employee per year for industrial, except that the maximum charge shall not exceed $250.00. During the year the Water Department had a surplus of $15,972.00. While expenses have risen in the past two years, the charts indicate the sound financial position.

The Department proposes a considerable improvement program, including a water softening plant, new water mains, booster station, etc., all of which are expected to be started in 1946.

The report also contains material on filtration, pumping, distribution, chemical analysis of the water, analysis of the sewage and affluent, and sewage plant operation, as well as the contracts proposed for converting Imhoff tanks to primary settling tanks, the building of digesters and appurtenances, along with other equipment.

AN EMPLOYEE PROFIT SHARING PLAN OF A MUNICIPALLY OWNED WATER UTILITY

Declared Legal by State Public Service Commission

By A. P. KURANZ
Manager
WAUKESHA WATER UTILITY
WAUKESHA, WIS.

THE idea of employees sharing in the profits of a manufacturing plant or any private business is not new; it has been established with various degrees of success, depending upon many factors. The plan adopted by Waukesha, which provides that employees share in the profits of a municipally owned utility or service, however, *is* new. To our knowledge, there is no other plan like this in effect anywhere in the country.

In developing this plan, there were many objections encountered which might be considered deterrents. Particularly outstanding was the argument that municipally owned utilities are, after all, owned by the community-at-large, and therefore any division of profits would in a sense deprive the owners of either a lower water rate or higher return to the city's general fund.

Commission Operation

The state of Wisconsin is fortunate in the operation of its publicly owned utilities in that the regulatory features and the rate making device are under the control of the Public Service Commission of Wisconsin, one of whose chief duties it is to see that the customer gets the best possible service at the least possible cost. Because the Public Service Commission is in that position, public utilities can operate more or less on what might be called the private enterprise basis. Section 66.06 of the Wisconsin Statutes is quite clear with reference to the establishment of governing bodies operating municipally owned utilities, particularly Sec. 10, "Management," and Sec. 11, "Charges," which read in part as follows:

Sec. 10.—Management. (a) In cities owning a public utility, the council shall, and in towns and villages owning a public utility the board may, provide for a nonpartisan management thereof, and create for each or all such utilities, a board of three or five or seven commissioners, to take entire charge and management of such utility, to appoint a manager and fix his compensation and to supervise the operation of the utility under the general control and supervision of the board or council.

(b) The commissioners shall be elected by the board or council for a term, beginning on the first day of October of as many years as there are commissioners, except that the terms of the commissioners first elected shall expire successively one each year on each succeeding first day of October.

(c) The commissioners shall choose from among their number a president and a secretary. They may command the services of the city engineer and may employ and fix the compensation of such subordinates as shall be necessary. They may make rules for their own proceedings and for the government of their department. They shall keep books of account, in the manner and form prescribed by the public service commission, which shall be open to the public.

This article, which appears simultaneously in the April, 1946, issue of the A.W.W.A. Journal, is being printed by authorization of the editor of the Journal.

An article by the same author, revealing Waukesha's Employee Profit Sharing Plan for the first time, was featured in the February, 1945, issue of this magazine. The accompanying article written a year later, in addition to describing this new departure in municipal employee compensation, brings up to date Waukesha's experiences with the profit sharing plan which has now received official sanction of the Wisconsin Public Service Commission as a legal process for a publicly owned utility.

Sec. 11.—Charges. (c) The income of a public utility owned by a municipality shall first be used to meet operation, maintenance, depreciation, interest and sinking fund requirements, local and school tax equivalents, additions and improvements, and other necessary disbursements or indebtedness. Income in excess of these requirements may be used to purchase and hold interest bearing bonds, issued for the acquisition of the utility, or bonds issued by the United States or any municipal corporation of this state, or insurance upon the life of an officer or manager of such utility, or may be paid into the general fund.

Basis for Decision to Institute Employee Profit Sharing

It will be noticed from these sections of the statute that first of all, municipally owned utilities are to be under a nonpartisan management and that they have the power to fix wages and salaries of the manager and employees. Section 11 (c) clearly stipulates what shall be done with the income of a municipally owned utility. It follows very readily that if the utility commission were out of line in establishing wages and salaries it would be reflected in the operation of the utility and, consequently, the Public Service Commission would be in a position to raise a question. It also seems reasonable that a profit-sharing plan is entirely proper and the only objection to it might be that it would upset the rate structure, and again, the Public Service Commission would be interested in this phase of it.

In considering such a plan, therefore, it was felt that if the arrangements did not in any way affect the final rate structure there could be little objection from any source. This was reasoned to be particularly true in the case of the water utility in Waukesha. Since the commission had established its financial program on the law as propounded in Sec. 11 in that proper provisions were made for local and school taxes, which are assessed against the utility on the basis of capital investment less depreciation, the utility is on the same basis as that of other manufacturing plants, so that the taxes the utility pays the city are on a basis exactly the same as if the utility were privately owned. Since the city, in the early days of the acquisition of the water utility, had invested funds through bond issue, it seemed reasonable that a dividend should be paid on this investment. This, too, is part of the financial setup in the case of the Waukesha Water Utility. In addition to this, an agreed upon sum, which varies from year to year, is paid to apply on the city's equity in the plant.

Since the Public Service Commission of Wisconsin has taken the stand supported by Statute 66.06 (11c), that a utility, even though municipally owned, is entitled to a fair rate on its investment, and if the utility rates are such that a profit is made, surely those who are in immediate charge of operating the utility have had much to do with making this profit possible. There, then, follows the line of reasoning that the employees are directly responsible for making this profit and no valid reason can be presented against their sharing in the fruits of their labor.

With that idea developed to its logical conclusion, it seemed feasible, just, and morally correct that the employees should share in this profit. The next step was to determine the basis upon which such profits should be shared, and the plan of using the employees' salaries and wages was the beginning point. The determination of the total amount was carefully studied and arrived at, on a very arbitrary basis, and it can be argued that there is no justifiable reason for doing it as it is done. Since the idea was so new, however, and since there was no pattern to follow, it was decided to make a bold move and the following motion was developed and put into effect covering the earnings for the years 1944 and 1945:

Waukesha Water Utility's Employees Profit-Sharing Plan

THAT, the employees shall share in the net income of the Waukesha Water Utility as determined by the auditors engaged by the Water Utility Commission each year.

THAT, the net income will be the amount remaining after retirement expenses, local taxes and dividends on the city equity have been deducted.

THAT, the employees share on the basis of 4 per cent of this net total, but that no employee's share shall exceed $200 per year.

THAT, each employee who has been with the Waukesha Water Utility for a period of six months during the year in which the plan is effective, share on the basis of his total wages and salary, including the Salary Savings Plan now in effect for most of the employees of the Waukesha Water Utility.

THAT, said profit-sharing payment shall be made after the auditors engaged by the Water Utility Commission have made their report.

THAT, the plan shall be considered as part of the wages and salaries paid to each employee.

It will be noted in the third paragraph that the figure 4 per cent of the net total was used, which is the figure referred to as "arbitrary" in a previous paragraph. One other feature of importance was that a limit of $200 per year was established because, since most municipally-owned utilities have one or two, or at least only a few, top-paid employees, there might be a feeling of inequality among the employees themselves and certainly from the employee's angle would create a much better feeling if the top-salaried men would be limited in their share. The total amount set aside under the plan, however, did not vary, so the amount that the manager and other top paid employees *did not receive* according to the sharing set-up was redistributed among the lower paid employees, so that in Waukesha's case the effect of the profit-sharing plan was a salary increase ranging from 3.6 per cent for the high-paid employees to about 8 per cent for the low-paid employees. The payment of the profit-sharing is made after the State Tax Commission auditors have completed their audit and after the utility's reports have been made to the Public Service Commission. These checks are issued within a few months after the close of the year in which the plan is effective.

Up to this point, all of the activity originated with the local water utility commission and proper action was taken to put the plan into effect locally. After this was done and the provisions of the employees' profit-sharing plan carried out on the basis of 1944 earnings, the plan was discussed with the Public Service Commission and after several exchanges of correspondence and visits to the Public Service Commission, attention was called by the Commission to Sec. 196.11 of the Wisconsin Statutes, which is as follows:

Sec. 196.11.—Profit Sharing and Sliding Scales. (1) A public utility may enter into any reasonable arrangement with the customers or consumers or with its employees, for the division or distribution of its surplus profits, or providing for a sliding scale of charges, or other financial device that may be practicable and advantageous to the parties interested. No such arrangement or device shall be lawful until it shall be found by the commission to be reasonable and just and consistent with the purposes of this chapter. Such arrangements shall be under the supervision and regulation of the commission.

It must be confessed that the statute apparently *did* provide the local water utility commission with legal authority to put the plan into effect, so the Public Service Commission thought that a public hearing should be held on the plan and set the date of the hearing for Nov. 20, 1945. On January 15, 1946, the utility received the following from the Public Service Commission of Wisconsin:

Public Service Commission of Wisconsin

The Commission Finds and Determines. That the employee profit-sharing plan of the Waukesha Water Utility, as discussed above, is reasonable and just and consistent with the purposes of Chapter 196 of the Statutes.

Dated at Madison, Wisconsin, this 15th day of January, 1946.

This finding and determination, of course, provided the legal authority to make the plan legally effective and it gave much support to the local water commission. If the net result of the plan as originally intended works out to any degree of success, the local water commission feels very strongly that it may become a permanent plan; at least the water utility commission feels that the plan should create not only better public relations but also better employee-manager relationships.

E-Zee Bee-O-Dee

(*From the* DIGESTER *of the Ill. Dept. of Health*)

A SHORT, simple formula for the calculation of biochemical oxygen demand, developed by Professor H. M. Gifft of Cornell University, and published in the August, 1943, issue of *Water Works and Sewerage,* has been modified slightly by us [The Digester] for easier calculation.

The formula can be used for all types, strengths, and conditions of sewages, wastes, and polluted waters, with results identical to other accepted methods. It has the advantages of correcting automatically for the dilution water B.O.D. and of requiring only one dissolved oxygen test prior to incubation. In some cases even the D. O. Test may be estimated with sufficient accuracy. So—o—o, if you'd like to use something that makes your B.O.D. work simple, try this method—it's easy.

$$\textit{Formula: } B.O.D. = (W - D) \times \frac{100}{p} + S - W$$

W = D.O. in blank after incubation
D = D.O. in dilution after incubation
S = D.O. in sample before dilution
P = per cent of sample in dilution

Example 1: B.O.D. OF RAW SEWAGE

Given: D.O. in blank after incubation = 8.0 = W
D.O. in dilution after incubation = 3.3 = D
D.O. in sample before dilution = 0.0 = S
per cent of sample in dilution = 2. = P

$$\text{Then: } B.O.D. = (W - D) \times \frac{100}{p} + S - W$$

$$\text{Step 1: } (8.0 - 3.3) \times \frac{100}{2} + 0.0 - 8.0$$

Step 2: $4.7 \times 50 + 0.0 - 8.0$
Step 3: $235 + 0.0 - 8.0 = 227$ ppm B.O.D. (Ans.)

Example 2: B.O.D. OF PRIMARY EFFLUENT

Given: D.O. in blank after incubation = 8.4 = W
D.O. in dilution after incubation = 2.2 = D
D.O. in sample before dilution = 1.1 = S
per cent of sample in dilution = 5. = P

$$\text{Then: } B.O.D. = (W - D) \times \frac{100}{p} + S - W$$

$$\text{Step 1: } (8.4 - 2.2) \times \frac{100}{5} + 1.1 - 8.4$$

Step 2: $6.2 \times 20 + 1.1 - 8.4$
Step 3: $124 + 1.1 - 8.4 = 116.7 =$ ppm B.O.D. (Ans.)

Example 3: B.O.D. OF FINAL EFFLUENT

Given: D.O. in blank after incubation = 8.6 = W
D.O. in dilution after incubation = 2.6 = D
D.O. in sample before dilution = 6.4 = S
per cent of sample in dilution = 25. = P

$$\text{Then: } B.O.D. = (W - D) \times \frac{100}{p} + S - W$$

$$\text{Step 1: } (8.6 - 2.6) \times \frac{100}{25} + 6.4 - 8.6$$

Step 2: $6.0 \times 4 + 6.4 - 8.6$
Step 3: $24 + 6.4 - 8.6 = 21.8 =$ ppm B.O.D. (Ans.)

Installing Cast Iron Pipe

A Motion Picture

The Cast Iron Pipe Research Association has issued its third sound motion picture, and this one. "Installing Cast Iron Pipe," like its two predecessors* is available to the water works fraternity without charge, except for return transportation.

Running about 22 minutes, this 16 mm. film features the journey of a carload of pipe from foundry stockpile to backfilling of an underground installation. The purpose of the film is to show accepted and generally followed methods of handling and installing cast iron pipe and to illustrate the difficulties resulting from careless or unsound practice. All operations from loading to handling on the job, jointing and backfilling are shown.

Prints of the film are loaned without charge or arrangements may be made to have a representative of the Association make the showing. Write to Thomas F. Wolfe, Research Engineer, Cast Iron Pipe Research Assn., Peoples Gas Bldg., Chicago, Ill., or to the sales office of any company member of the association.

* "Pipe and the Public Welfare" and "Health and the Cycle of Water."

FILTER SAND SPECIFICATIONS*

By THOMAS M. RIDDICK
Consulting Engineer and Chemist
NEW YORK

The original work on filter sand was done by the late Allen Hazen about 1890. Hazen introduced the terms "effective size" and "uniformity coefficient" which are in use today. As Baylis has pointed out, however, Hazen's work was primarily applicable to "slow" rather than to "rapid" sand filters.

Sand employed in the former was often unwashed and ungraded and hence contained a relatively high per cent of "fines" and the sizes extended over a wide range. It was not uncommon to have an effective size as low as 0.2 mm. with a uniformity coefficient of 3.0 or higher.

With these conditions, Hazen found that the fine sand (0 to 10 per cent) had about as much effect upon filtration efficiency as practically all the other sizes combined.

Today, the "fines" (retained on 150, 100 and 65 mesh), as well as the coarse sand (retained on 12 and 14 mesh screens) are eliminated by the producer through washing and screening. Under these circumstances, effective size and uniformity coefficient lose much of their original significance.

There are two screen scales available. The clear opening between meshes of the "square root of 2 series" increases in the ratio of 1.414. This is entirely adequate for filter sand analysis. The greater refinement enabled by the "fourth root of 2 series" (1.189) is not warranted.

According to the theory of hydraulic subsidence, backwashing *should* grade sands within a layer, leaving the coarsest material at the bottom and the finest at the top.

Filter Sand Requirements

A filter sand should be used which will produce a clear and sparkling effluent—free from coagulant—under the *worst* rather than *average* conditions of floc formation. The poorest coagulation is generally experienced during the fall season.

Filter sand should also *completely* prevent the passage of activated carbon when this is applied to the top of the layer. This important qualification has arisen only within the past several years.

Effect of Fine Sand on Clarity of Effluent

Repeated instances have shown that when 35 (and some 48) mesh sand was added to either pressure or gravity filters deficient in these sizes, immediate improvement in the clarity of the effluent was noted. This led to the author's firm conviction that fine sand is essential to the production of a finished water with a turbidity comparable to distilled water.

Although fine sand will undoubtedly give a shorter filter run than coarse, this is partly due to the removal of a greater per cent of suspended matter from the treated water. Long filter runs are more dependent upon the design and efficiency of the mixing basin and the retention period of the sedimentation basin than upon the size of sand employed.

The loss of head through either fine or coarse sand takes place principally at the surface as is shown by the complete recovery of a slow sand filter after skimming.

From both theoretical and practical considerations, all 65 mesh sand should be excluded, or, in other words, the "finest" sand which can be maintained in a layer at 50 per cent expansion is the 48 mesh size.

Stratification of Filter Sand

Table I gives the results of analyses of samples collected at the Danbury, Conn., plant. The amount of sand retained on the 65 and 14 mesh sieves was less than 1 per cent, which, for practical purposes, may be disregarded. The significant amounts in all filter sand analyses are those retained on the four sieves: 20, 28, 35 and 48 mesh.

This table lists seven individual analyses, each showing "per cent retained" and "per cent passing." From the latter values have been computed the "effective size" and "uniformity coefficient" found in each stratum.

The top ½ in. layer of sand contained approximately 80 per cent of 48 mesh and 20 per cent of 35 mesh sand. The effective size for this stratum was 0.35 mm. and the uniformity coefficient 1.17. Most of the stratification took place within the top 2 in., although a definite gradation in both 48 and 28 mesh sizes is also seen from top to bottom. This filter showed the best hydraulic grading of those sampled, though mud balls were present at all depths. The author considers this an ideal grading, and the presence of the large per cent of 48 mesh on top of the filter gives excellent reduction in turbidity.

The results of Mamaroneck, N. Y., samplings show this sand had an effective size of 0.45 mm. and a uniformity coefficient of 1.32, and is well adapted to good filtration. Practically all stratification took place within the top 2 in., which is the region mainly responsible for the removal of floc and turbidity. The per cent of 48 and 20 mesh was small, and the sand was roughly two-thirds 35 mesh and one-third 28 mesh.

At Nyack, N. Y., the per cent of 48 mesh was low, but the bulk of this was found in the top 2 in. and practically all in the top 6 in. The stratification of the 35 mesh is evident only in the top 2 in. A small per cent of 20 and 14 mesh sands were present and these were uniformly distributed from 2 in. below the top to the bottom. This demonstrates in general the advisability of excluding if possible the 14 and perhaps 20 mesh sand entirely. The effective size of the entire layer was 0.50 mm. and the uniformity coefficient 1.38. Since the placement of this combination of sand sizes, the filter has consistently produced an effluent with turbidity quite comparable to distilled water and has not permitted the passage of any carbon applied to the top of the filter, when applied one-half hour after backwashing.

At Ossining, N. Y., little stratification was evident. The proportion of 20 mesh sand (which was low in the previous filters) was relatively high in this filter. Two inches of fine sand (35 and 48 mesh) were added and resulted in a lowering of

ON PAGE 218 of the July issue of *Water Works & Sewage* there appeared an article on Filter Sand Grading. Written by J. Tarrant of Ruislip, England, the article contained a nonograph relating uniformity coefficient, effective size and mesh size.

Following the publication of this article, Cecil Calvert, Supt. of Filtration, Indianapolis Water Co., wrote to say that his company had used the specifications proposed by the author in 1939 and had found them completely satisfactory. In view of this comment, the editors of *Water & Sewage Works* asked the author to abstract his original article (*JAWWA* **32**, 121, 1940) for use as Reference and Data material.

The original article was developed from a study of filter sand, filter sand classification, effect of wash water rise, and location of wash water troughs at six filter plants, as well as the theory of filter bed expansion, and sand specifications.

For the present purpose, it is only necessary to abstract the information and data on sand classification together with the filter sand specifications the author proposed at that time, as a result of those studies.

TABLE I

Analyses of Sand Filter No. 5, West Lake Plant, Danbury, Conn., August 11, 1939

Sieve Number	Depth in Layer 0"-½" Ret Per cent	0"-½" Pass Per cent	½"-2" Ret Per cent	½"-2" Pass Per cent	2"-6" Ret Per cent	2"-6" Pass Per cent	6"-12" Ret Per cent	6"-12" Pass Per cent	12"-18" Ret Per cent	12"-18" Pass Per cent	18"-24" Ret Per cent	18"-24" Pass Per cent	24"-28" Ret Per cent	24"-28" Pass Per cent	Total Grams	Total Ret Per cent	Total Pass Per cent
65	1.8	...	1.0	...	2.1	...	0.7	..	0.4	...	0.1	...	0.6	...	6.7	0.9	...
48	80.2	1.8	62.1	1.0	39.1	2.1	20.3	0.7	16.3	0.4	11.9	0.1	9.2	0.6	239.1	34.2	0.9
35	18.0	82.0	36.9	63.1	55.7	41.2	60.2	21.0	61.3	16.7	59.6	12.0	49.0	9.8	340.7	48.7	35.1
28	...	100.0	...	100.0	3.1	96.9	16.3	81.2	19.3	78.0	25.4	71.6	26.1	58.8	90.2	12.9	83.8
20	...	...	...	...	...	100.0	2.5	97.5	2.7	97.3	3.0	97.0	5.2	84.9	13.4	1.9	96.7
14	...	...	...	...	...	...	...	100.0	...	100.0	...	100.0	3.7	90.1	3.7	0.5	98.6
8	...	...	...	...	...	...	...	...	...	...	...	...	6.2	93.8	6.2	0.9	99.1
														100.0	700.0		100.0
Effective Size—mm.	0.35		0.36		0.36		0.39		0.40		0.42		0.42				0.38
Uniformity Coefficient	1.17		1.17		1.36		1.41		1.41		1.39		1.45				1.40

*An abstract of an article on "Filter Sand" which appeared in the January issue of the *Jour. AWWA*, p. 121, 1940.

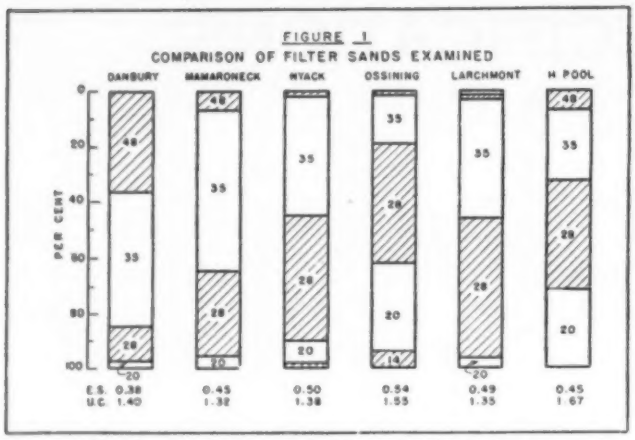


Fig. 1. Comparison of Filter Sands Experiment

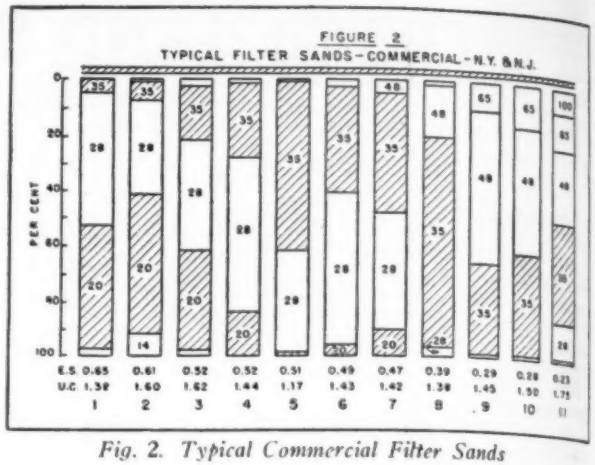


Fig. 2. Typical Commercial Filter Sands

turbidity of the effluent from 0.4—0.5 to 0.0—0.2 ppm.

At Larchmont, N. Y., the hydraulic grading was very good, but contrary to the preceding findings, the coarsest sand (28 and 20 mesh) was found at the top, and the finest sand (35 mesh) was predominant at the bottom of the layer. This sand was jet black and coated with 12 per cent of manganese oxide, computed as Mn. The specific gravity was determined for the 35 and 28 mesh sands respectively, and it was found that the larger sizes were lower in weight per unit volume than the smaller sizes due to the build-up of the porous coating. The effect of density was sufficient to cause complete reversal of normal hydraulic subsidence, but this is in accordance with Stokes' law, which states that the rate of subsidence is proportional to the square of the diameter and to the difference between the specific gravity of sand and water. This filter, however, functions as a contact layer for removal of manganese as well as for filtration.

The Highbridge Pool filter was sampled since the lip of the wash water trough is 54 in. above the top of the sand, which is approximately twice the conventional distance. Here we note a relatively large per cent of 20 mesh and a reduction in the 35 and 48 mesh sizes. This naturally greatly increases the uniformity coefficient. No stratification existed below the 2-in. depth.

Comparison of Filter Sands Studied

Fig. 1 shows a comparison of all filter sands examined. Effective sizes ranged from 0.38 to 0.54 and uniformity coefficients from 1.32 to 1.67. The Danbury filter, with low effective size and uniformity coefficient, showed the best stratification. The stratification at Nyack was better than at Ossining, which may be due to the use of three sizes of sand at the Ossining plant as compared with practically two sizes at Nyack.

Comparison of Commercial Filter Sands

Fig. 2 gives typical commercial filter sands produced in New York and New Jersey. Numbers 1 and 2 would give the longest filter runs. Due to the large amount of 20 mesh and the inclusion of some 14 mesh, No. 2 would probably require less backwashing. The amount of 35 mesh sand present, however, is too low to provide efficient filtration during times of poor floc formation. The characteristics of these sands are more similar than is indicated by the existing variation between effective sizes and uniformity coefficients.

Number 3 has a larger per cent of 35 mesh, but too great a per cent of 20 mesh. Number 4 is a fair filter sand, although it would be preferable if the 35 mesh were increased, and the 20 mesh decreased.

Numbers 5, 6, 7 and 8 are the best of the lot, and No. 8 would undoubtedly give the clearest effluent, but shortest filter run. It is adapted to a plant with a sedimentation period of 4 to 6 hours. Number 6, with a uniformity coefficient of 1.43 and an effective size of 0.49 mm., would be best for a 3-hour basin. The small amount of 48 mesh sand would be found largely at the top of the layer.

Numbers 9 and 10 are useful for addition to an existing filter which is lacking in "fines." Number 9 could be added to No. 1 to very good advantage, and would result in a marked improvement of this sand. Number 11 is worthless for filters since it contains too much 100 and 65 mesh. It would increase the uniformity coefficient when added to practically any sand, and at least 22 per cent (representing the 100 and 65 sizes) would soon be lost through backwashing.

Selection of Filter Sand

The bulk of so-called filter sands on the market today are in reality screened for moulding and blasting. The demand for filter sand is exceedingly low and amounts to only two-tenths of 1 per cent of the total sand sold commercially, excluding that used for building, paving and railroad ballast.

In selecting a filter sand it is preferable to take a standard grading rather than have a producer change his screens to meet rigid specifications. The output of several companies should be examined. If necessary, two sands may be blended when the filter is built. If this is done by the producer, the shipment may materially differ from the sample submitted.

In the opinion of the writer, the 48 and 20 mesh sizes should be limited to about 10 per cent each, with the latter excluded if possible. The 35 and 28 mesh sizes should be present in about equal proportions. If a long sedimentation period is provided, the 48 mesh sand may be increased slightly. Sands of this type will have an effective size of about 0.50 mm.; a uniformity coefficient of less than 1.45.

The specifications with regard to sizes suggested by the author are given in Table II.

The selection of torpedo sand is very important since 35 mesh sand is present next to this fine gravel. If it is too coarse it would seem to provide a ready passage of the 35 mesh material down into the underdrains. On the other hand, it should not be so fine as to be lifted during backwashing. The writer believes that torpedo sand should pass a No. 6, and about 50 per cent each should be retained on No. 8 and No. 10 mesh screens (14 and 20 mesh sand will not remain in place).

In this instance, the maximum diameter of particle is 3.33; minimum, 1.65; and average, 2.5 mm. The average size of 35 mesh sand is 0.50 mm. The average diameter of torpedo sand is 5 times the diameter of the 35 mesh. From a theoretical standpoint, the maximum ratio to prevent passage of fine sand is 6.4. It would seem desirable therefore to limit the 48 mesh sand to that quantity which will remain in the top 6 in. of the filter.

TABLE II

Suggested Size Specifications

Sieve Number — √2 Series Tyler Standard	Sieve Number — U. S. Series Equivalent	Sieve Opening Millimeters	Per Cent Retained on Sieve Minimum	Per Cent Retained on Sieve Maximum
65	70	0.208	0	1
48	50	0.295	0	9
35	40	0.417	40	60
28	30	0.589	40	60
20	20	0.833	0	9
14	16	1.168	0	1

Conclusions

1. The finest size of sand that should be used in a rapid sand filter employing 50 per cent expansion is that retained on a 48 mesh sieve.

2. Thirty-five mesh sand (*average* size 0.50 mm.) is required for low turbidity of effluent and to prevent the passage of activated carbon.

3. In specifying filter sand, it is preferable to use "per cent retained on" rather than "effective size" or "uniformity coefficient."

4. The 48 and 20 mesh sizes should be limited to not more than 10 per cent each, with the latter omitted if possible. The predominant sizes should be 35 and 28 mesh, and these should be present in approximately equal amounts.

5. Torpedo sand or fine gravel should be carefully selected as to size.

COAGULATION WITH FERRIC SALTS*

With Particular Reference to Ferric Sulphate and Its Use

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ALL water works operators are probably familiar with one form or another of coagulation with iron salts. There is an aversion among most water works operators toward iron salt coagulation, this aversion being improperly founded and probably arising from difficulties encountered in coagulation with ferrous sulphate. Although this paper is devoted to coagulation with ferric sulphate, a brief review of coagulation with other types of iron coagulants will clarify the inherent differences between coagulating with ferrous salt and ferric salt.

Ferrous Sulphate as a Coagulant

The most common form of iron coagulation, that is the one most familiar to all of us, is coagulation with ferrous sulphate and lime. This form of coagulation has been called, by many authorities, the most economical means of water coagulation. I do not entirely agree with this statement, however, since many of the difficulties encountered with the actual coagulation drive up the total cost to the point that economy is hardly a consideration.

Ferrous sulphate itself is water soluble and will remain in solution in any water near neutral pH over a long period of time. In order to have any coagulating value whatsoever, the ferrous sulphate must be converted to a ferric salt. This is normally accomplished by raising the pH with lime and then adding the ferrous sulphate. In the presence of dissolved oxygen the reaction produces ferric-hydroxide, the same coagulating material obtained with almost any ferric salt. A certain portion of the ferrous sulphate, however, must be converted to ferric-carbonate which has absolutely no coagulating value. From this it can be readily seen that only a portion of the iron actually available in the ferrous sulphate is utilized in coagulation. Furthermore if excess lime is added, an unbalanced water may be made and the sand grains on the filters may be seen to grow. If an insufficient amount of lime is used, some of the ferrous sulphate will remain in solution and will pass the filters still in solution. This will cause red water difficulties in the distribution system as well as causing inefficiency in the actual coagulation process.

These difficulties alone are sufficient to rule against the use of ferrous sulphate and lime in most water purification plants. Ferrous sulphate, however, has a tendency to cake and cannot be normally used in all types of dry feeders due to this tendency. If stored in large bulk hoppers, it is often known to cake in these hoppers and may even require the use of air hammers to break it. The most common method of storing ferrous sulphate is of course in water proof bags and most plants do use the material in that form.

Ferrous sulphate can also be used with chlorine. This treatment is normally known as the chlorinated copperas treatment. The ferrous sulphate is first put into solution and then chlorine is added in a ratio of approximately one to seven. The chemical reaction produces a mixture of ferric-sulphate and ferric-chloride. This is a very excellent coagulant and certainly will do a fine job of coagulation. The objections to this type of treatment, however, are that the ferrous sulphate is still difficult to feed and furthermore the chlorination of the copperas causes fuming and unless the process is properly protected, corrosion of the surrounding apparatus often occurs. Furthermore, this feeding apparatus is rather expensive and must be rather carefully controlled at all times.

Ferric Chloride

Ferric chloride is not normally employed in water plants due to its physical characteristics. The anhydrous material is far too expensive to use. The liquid material, although a cheap coagulant if the plant is located near a source of manufacture, requires rather expensive equipment for handling. All unloading equipment must be rubber-lined, and rubber-lined storage tanks must be provided, all feed lines must be rubber-lined and in the end a very expensive installation is required.

Ferric Sulphate

Ferric sulphate has been long recognized by the general water works trade as an efficient coagulant but its general use was not adopted due to a very high price of the chemical. Until a relatively few years ago, in fact during the last decade, ferric sulphate was considered too expensive for normal use in water treatment plants. At that time, however, two manufacturers started making this chemical as a by-product and the price now approaches that of filter alum. Therefore, with the rather high cost of securing this chemical eliminated, its use began to pick up rapidly in water and sewage plants throughout the United States.

Unfortunately, however, for the water works industry as a whole, the war has presented a very rapid expansion of its use. In the first place, ferric sulphate is used in the pickling of stainless steels and brass and is used in the catalysts for the manufacture of synthetic rubber, it is used in the manufacture of certain types of insulating boards, it is used in the manufacture of foam fire extinguishers, as well as many other industrial uses.

All of these industrial uses have claimed a large percentage of the total production of ferric sulphate during the war period. Furthermore, there are certain processes in the manufacture of ammunition powder that even the slightest trace of alum would disrupt. Therefore some coagulant other than alum had to be resorted to. In most instances, these plants are now using ferric sulphate. With the end of the war ferric sulphate has again become available for new water works contracts. Were it not for these facts there would undoubtedly have been a much broader use of ferric sulphate by now.

Dissolving Ferric Sulphate

Ferric sulphate is not difficult to use but its use is different from that of alum and certain considerations must be made. In the first place, ferric sulphate is by no means as soluble as alum. This requires the use of different types of dissolving equipment. Ferric sulphate, peculiarly enough, is more soluble in a small rather than in a large volume of water due to the fact that a more acid solution is rendered and secondly because the heat of solution of ferric sulphate is not dissipated and a warmer water is obtained in the dissolving pot. Normally, it is considered that the proper water salt ratio is three parts water to one part of ferric sulphate by weight.

The ferric sulphate is first fed into a dissolving pot and water is added in the proper ratio. The material must then be violently agitated for a period of about thirty minutes before it goes into solution. This may sound rather complicated but it is a relatively simple process to put the material into solution.

This dissolving pot is not large. For example, take a water plant treating twelve million gallons of water per day with a maximum dosage of three grains per gallon. For maximum feed conditions, a twenty minute retention period in the mixing pot and a two to one water ratio are normally sufficient. Under such conditions a twenty gallon crock would be a sufficiently large solution pot. A larger solution pot could of course be used without difficulty if it should be desired to do so.

Metering is relative simple; a rotameter is probably the most common metering device for this purpose and such a rotameter should read directly in pounds of water per hour, and should be so selected for size that the rotor rides about half way in the tube for normal operating conditions. The Omega Machine Co. has made an Archimedes wheel as a measuring device for water on such feeders or a very simple home-made device can be utilized which is merely feeding the water into a constant level box, the overflow going to the dissolving pot outlet, and the water to the dissolving pot controlled by a pinch cock.

The dissolved material from the solution pot is very strong. This should be further diluted before going to the raw water. In fact, a 2 per cent solution has been found to be most satisfactory for ferric sulphate or alum, or any other coagulant for that matter. Of course this 2 per cent solution strength need not be accurately maintained and need be only approximated. It seems that any stronger solution will have a tendency to react with only a small portion of the raw water thus failing to give a uniform coagulation of the entire mass of water.

Solution Pot Equipment

Agitation of the dissolving pot is best secured by a small type mixer, probably a ⅛-hp. portable mixer. This should be

* This paper, presented before the W. Va. Section of the Am. Water Works Assn., is here published by permission of the Association.

of the "Lightning" type or similar, normally costing from $75 to $85 each. Complete installation for the average small feeder will run approximately $100 per feeder to install the proper dissolving equipment.

It is interesting to note here that most plants having tried ferric sulphate have resorted to this type of dissolving equipment even though they are still using alum. They have found that this type of dissolving equipment accomplished several advantages even with alum. In the first place, they are able to maintain a true solution of alum and thus all the alum fed is utilized. In many studies it has been found that much of the alum going into the raw water was undissolved. A sizeable portion of this material settled out into the sludge and never did properly react with the water. Still other material was carried beyond the mixing basin before becoming properly dissolved and thus carried free alum through the filters. This not only wastes alum but is not a condition to be desired in any plant. This change in method of dissolving alum is particularly noticeable during the cold weather. Many of the cold weather problems of plants using this solution pot dissolving technic have been eliminated.

It is interesting to note that the new Fall Creek plant at Indianapolis, Indiana, built only a few years ago, employs a large stainless steel dissolving pot, agitators, rotameters for controlled alum solutions, plus controlled water temperature for feeding to the alum thus assuring a complete solution of a known strength at all times. This plant has been most economical in its operations.

The blades and shaft of the agitators must be of some acid resisting material. Probably the most common is 18-8 stainless steel. This is strong and at the same time gives excellent wearing qualities. Wooden paddles and shafts or wooden shafts and porcelain impellers may be used equally well, but are not quite as long-lived as stainless steel.

The best material for the dissolving pot is probably lead, but other materials may be used. Stainless steel is very good but it is too expensive for the average plant. Rubber-lined steel tanks are excellent but if the temperature in the pot should rise above 140° F, the rubber lining is damaged and the pot may fail. For this reason it is not generally considered the best practice to use a rubber-lined dissolving tank. Lead-lined dissolving pots are satisfactory but lead-lining is so thin that the abrasion from the insoluble particles of ferric sulphate may cause it to wear through rather rapidly, thus allowing the material to attack the iron or steel of the pot shell and thus cause leaks. Crockery and Duriron are both very satisfactory for the dissolving pot but both have the same disadvantage in that they are brittle and are rather easily broken by impact. Wood dissolving pots are quite satisfactory but have the disadvantage of requiring an appreciable amount of maintenance to keep them coated with some acid-resisting paint.

The lines from the dissolving pots to the point of application must also be given consideration. These lines may be of any acid resistant material. A rubber-line is preferred as it is easy to clean out and cheap to install. Rubber-lined steel lines are used in a number of plants and are very satisfactory. Lead pipe may be used very satisfactorily, particularly if it is protected from damage from impact.

Equipment for handling ferric sulphate up to the point of solution is exactly the same as that for handling alum. The material is no more corrosive than alum in the dry state. Thus any standard dry feeder is satisfactory for the material. Ferric sulphate will store in bulk hoppers, bags, or other means the same as used for storing alum in any plant. It does not arch in the feeders and will store over long periods of time without lumping.

Floc Formation

Ferric sulphate is somewhat more active chemically than alum and the hydroxide is produced more rapidly than is the case with alum. This means that the mixing characteristics of the plant should receive additional attention if ferric sulphate is to be used. The coagulants should be added at the point of maximum agitation. The quick mix is very important if good coagulation is to be obtained. A hydraulic jump probably is the most rapid and complete pre-mix but there are a number of mechanical pre-mixers that give excellent results. The object of the pre-mixers is primarily to distribute all the chemicals throughout the main body of raw water before the chemical has sufficient time to react with the raw water. This means that a violent mix is to be preferred although any mix that works satisfactorily for alum should work satisfactorily for ferric sulphate. The coagulation or slow mix should normally be a little bit longer than that employed for alum. Alum *starts* to form its floc more slowly than ferric sulphate; then the floc forms very rapidly, and additional mixing beyond that point does little or no good.

On the other hand, with ferric sulphate, the floc starts to form immediately from the introduction of the chemical into the water and floc development continues at a rather slow and uniform rate for approximately forty minutes before it starts to level off. This floc formation time will of course depend on water characteristics, temperature and other variables but forty minutes may be considered the general rule. Ferric sulphate of course works excellently in many plants employing much shorter mixing or coagulating periods but these plants probably are not operating at maximum efficiency and even greater savings would be possible if longer mixing periods were possible.

Characteristics of Ferric Sulphate Coagulation

With this information on the method of feeding ferric sulphate it might be well to consider some of the characteristic reactions within the plant. Ferric sulphate is far less touchy to turbidity changes than is alum. That is, a change of turbidity that would require a change of dosage for alum coagulation, may require no change of dosage with ferric sulphate. For instance, one plant on Lake Michigan using ferric sulphate regularly, has machines set for a specific dose at all times. Variations in the turbidity of the lake water, although relatively small, are noticeable with alum coagulation but are not noticeable with ferric sulphate coagulation. Likewise a mid-west plant is subject to rather high flash turbidities which do not cause any particular trouble. True, the dosage should be increased for higher turbidities as a safety factor but as long as just a small excess dosage is being used, a considerable change in turbidity may occur and yet good coagulation can be maintained throughout this period. This fact is quite helpful in plants where highly trained operators are not available at all times.

The percentage of iron in ferric sulphate is higher than the percentage of aluminum in filter alum. Therefore ferric sulphate is generally considered a stronger coagulant. This means that considerably smaller dosages can normally be used. In many plants, it is found that from thirty to forty per cent less ferric sulphate can be used than alum. This is not true in all water plants, however, and cannot be taken as an absolute rule. Always bear in mind that both coagulants have their place in the water works field and no absolute positive rule regarding their comparative performance can be laid down.

Ferric sulphate is particularly advantageous in water softening plants. It is not sensitive to changes in pH in the high pH range encountered in softening. The very careful pH control required in softening plants using alum coagulation is not essential in ferric sulphate coagulation.

Alum is probably a little more efficient than ferric sulphate in coagulation at or near a neutral pH, but above pH 7.8 or below pH 6.4 ferric sulphate will be found more efficient.

If lime or other pH control measures are used in ferric sulphate coagulation it is generally considered best to apply such pH control ahead of the coagulant. Therefore in a straight coagulation plant employing pH control for corrosion control in the distribution system, the lime should be added to the water before the addition of the ferric sulphate. This is an advantage as smaller dosages of lime are thus employed and less lime is carried on to the filters to clog them. Ferric sulphate is also very responsive to break-point chlorination. It is generally found that break-point chlorination very definitely improves the coagulating ability of ferric sulphate and so if this type of treatment is used it should be ahead of the coagulant, if at all possible.

Color Removal, Taste and Odor Control

If the problem is that of color reduction, ferric sulphate may or may not be the answer. If using break-point chlorination for the color control, ferric sulphate will undoubtedly be a distinct advantage. If, however, coagulation takes place slightly below pH 7.0 and color control is by coagulation with alum, in most instances the alum will be found to be the cheapest coagulant to use. On the other hand if it is necessary to reduce the pH below 6.3 or 6.4 to remove the color by alum coagulation, ferric sulphate may again prove to be the most economical coagulant.

For taste and odor control by coagulation, ferric sulphate is generally very effective. Many tastes can be removed by coagulation provided that they are not first fixed by a definite change in pH. This permits lime to be added slightly ahead of the coagulant and thus maintain the raw water pH throughout the coagulating process. If this can be done, many tastes can be removed by coagulation which otherwise would be fixed if alum without lime were used and the coagulating pH thus lowered.

If iron is present in the raw water in any substantial quantity, the iron will normally react with the alum and interfere with coagulation. This same iron, however, in conjunction with a ferric coagulant will actually prove to be an aid to coagulation and dosages can be reduced to a minimum. This is an important fact to remember in areas where water plants are troubled with iron in the raw water.

LOCATING LOST SEWERS AND MANHOLES*

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IF YOU have sewers, drains and manholes for which you have no records or for which available records are inaccurate, then, perhaps, some of the experiences recounted here may be of practical interest.

The settlement of New Rochelle, New York, was started in 1688, and it has enjoyed a consistent and rapid growth since then. It was incorporated as a village in 1858 and became a city in 1899. The 1940 federal census gives the population as 58,408. The area of the city is 10½ square miles.

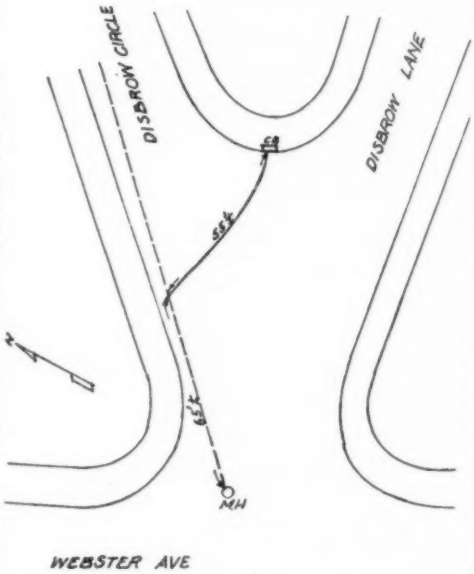
The population area of the city has largely expanded by individual real estate developments to which were assigned definite names, such as Residence Park, Halcyon Park, Highland Park, etc. In the early days, each real estate developer tried to be exclusive and laid out dead end streets. The streets were laid out with the definite intention of not connecting with the streets of any other development. Within recent years this situation has been corrected by the creation of a city planning board which has set up a master city plan, and every developer must have his plans approved by the planning board before he can start work; also, all plans for sewers and drains must now be approved by the Department of Public Works and the construction inspected by that department.

For many years, however, sewers and drains were installed by the developer under no city supervision; no maps were submitted to the city, and in some cases I have found the developer had no map showing the course of the pipe. I have found instances where the developer has laid pipes across lots, and when he sold the properties crossed by the pipe he retained no easement covering the repair or maintenance of the pipe.

I have found one instance where in 1894, by order of the Board of Health, the city laid a 15-inch drain meandering along the course of a brook across lots, filled in the bed of the brook over the pipe and never secured any easements from the property owners. A few years ago it became vitally necessary to increase part of this drain to 36 inches, and the city had to pay a substantial amount for the easement, although the 15-inch pipe had been occupying the same property for over forty years.

I have had occasion to investigate a situation where there were constantly recurring floods. I found a 24-inch vitrified tile drain completely plugged. From a point where an open brook entered this pipe, it was approximately 1,000 feet to the first manhole. The city had no plan of this drain. I contacted the developer and found he had no plan, but I took him to the location and he showed me, as well as he could remember, the course of the drain, which, it seemed, followed a reverse curve. The drain was laid with open joints, and went through a swampy area in which there were a number of willow trees.

This led me to believe that the stoppage was in all probability caused by the entrance of willow roots into the drain. This spot was too far away to be reached satisfactorily with flexible sewer rods from either opening in the drain. We therefore decided to put in a manhole in the swamp area. After four days of digging we finally located the drain at a depth of about 5 feet and opened it. We found the pipe completely filled with roots and it took almost two weeks of work to clear the line. This experience made me feel that there ought to be some means of locating underground sewers and drains.



Location of point of intersection of catch basin lateral and main drain simplified by use of M-Scope at New Rochelle, N. Y.

I was familiar with the use of the M-Scope in locating underground water mains. So I asked the salesman to try it out on this drain with flexible sewer rods inserted in the drain. We got 238 feet of rods in the drain, placed the transmitter on the rod and also, by means of the wire and clip provided, connected it to the rod. With the receiving set we were able easily to follow the course of the curving drain for about 200 feet. At this distance the signal became rather faint, but one man with keen ears followed it for the full distance of 238 feet.

We then rigged up the transmitter and receiver on the carrying sticks and went over the line to see if by any chance we might find any hidden manholes. At one point, right over the line, we got a sharp signal and started to dig feverishly for the manhole, only to find that a steel barrel hoop was buried in the ground. However, this demonstration satisfied me that the instrument could be used satisfactorily, for the purpose of locating both tile drains or sewers and buried manhole covers.

At another time, to relieve a flood condition, we wanted to install a new catch basin in the middle of a block and connect it to an existing drain at a manhole shown on the map at about the point we wanted. There was, however, no evidence of the manhole on the ground. With the M-Scope we located the manhole within a few minutes, just off the paved area, and under about 3 inches of sod. This time it was really the manhole.

Another time the map showed a drain manhole on the east side of the street at a certain intersection. The M-Scope gave no signal on the east side of the street but gave a clear signal on the west side of the street and, sure enough, we found the manhole about 8 inches deep under the macadam pavement.

We had a sewer and a drain running through a private right-of-way. The map showed a manhole on each. The sewer and drain had been installed 14 years ago. For the past several years periodic efforts had been made to locate the manholes, but without success. This right-of-way had several angles in it. It passed through a fine estate and the property was so thickly landscaped with evergreens, paths, gardens, etc., it would have been almost impossible to have resurveyed the right-of-way without doing real damage to the property. With the M-Scope we located and uncovered both manholes within an hour. One manhole was covered with about a foot of dirt and the other with about 3 inches.

Another time we tried to follow the course of a drain, about 15 feet deep, which ran through territory covered with thick brush, so that it was impossible to follow the line directly from the manhole. The first open land was almost 200 feet away from the manhole and transmitter, but no signal whatever could be picked up there. We cut an opening in the brush about half way back, and were able to pick up the signal at that point. For deep drains it is necessary to limit the distance from the transmitter.

Another failure we had was in trying to find a couple of catch basins that we thought were located near an abandoned railroad bridge, where the land is thick with brush. Following along the gutter we picked up a signal on each side of the road and thought we had located the catch basins, but digging down we found nothing. I then found I could follow the signal across the road. There is a 24-inch drain at this point, installed by the old railroad company, and apparently 24-inch cast iron pipe was used to cross the road. This experience illustrated the fact that in locating catch basins or manholes, when a signal is picked up, it must be tested from every direction to see that it is not emanating from a pipe line.

*From *Sew. Wks. Jour.* 17, 199 (1945). Published here by permission of the Fed. Sew. Wks. Assns.

In a road improvement job we had a 15-inch storm drain in the road and a catch basin on one side of the road with a lateral connecting to the drain at an unknown point. We wanted to install a new catch basin on the opposite side of the road, connect this basin to the drain at the same point as the lateral from the old catch basin and build a manhole at the junction of the three lines. The accompanying sketch illustrates the condition we faced. We ran the flexible rods through the lateral from the old catch basin and, much to our surprise, found that it followed a curved line. As a check for the point of intersection, we ran the rods up the 15-inch drain from the manhole at Webster Avenue and located it on the ground. At the indicated point of intersection we dug down and found ourselves at the exact point desired. If we had simply assumed that the original lateral had been laid on a straight line as it should have been, we would have dug for days before we would have found the right spot.

We have also used the M-Scope to trace the meandering drain laid in 1894 and mentioned at the beginning of this paper. Here the instrument proved very effective and also located two manholes which had long been covered along its course.

In conclusion, I will say that I have found the M-Scope very effective for locating the position of shallow drains for distances of about 200 feet, and for deep drains about half that distance. It is excellent for locating manholes as long as care is used in its operation, and it is understood that it will pick up any metallic substance underground, be it manhole barrel hoop or pipe line.

EQUIPMENT AND TOOLS FOR SEWAGE WORKS*

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A WELL designed and well equipped sewage treatment plant should have a complete complement of tools and equipment necessary to its proper operation. Quite often it is impossible to foresee, in the design of a plant, just what tools and equipment will be needed, and yet some attempt should be made to provide as much of the equipment as possible. Likewise, in the operation of a treatment works conditions and situations change, thereby making it necessary to increase the inventory of equipment and tools. In either case a list of tools, equipment, and materials for the operation of a sewage disposal plant will be helpful as a guide either to the designing engineer or the operator. Such a list has been prepared and is presented herewith.

Irrespective of the items appearing on any general list, it is essential that the manufacturer or supplier of various machines and equipment furnish the special tools and spare parts for their equipment and machines.

Obviously, various types of plants require different types of equipment. The number of operators available, their previous trades and experience likewise modify these lists. Some operators are adept in carpentry while others have a flair for working in metals. In either case it would be well to expand on the tools and equipment suggested in the following to meet the particular ability of the operators.

At some plants only the smallest repairs are handled, while in others there are sufficient personnel to permit practically all of the maintenance repair work to be done at the plant. Accordingly the tools will have to be modified to meet these conditions. The proximity of repair services likewise influences the type of tools that must be available.

* In the preparation of this list the writer is indebted to Marshall E. Ferguson, Field Technician of the Interstate Sanitation Commission, and to Joseph Doman, Sanitary Engineer, Department of Public Works, Greenwich, Connecticut, and Leslie E. West, Chief Engineer of the Elizabeth Valley Joint Meeting, who have reviewed the list and very generously offered their comments. The list was also checked against an inventory of the equipment and tools at the sewage treatment plant of the Belgrave Sewer District of which Herbert O. Johnson is superintendent.

The following list is indicative of the type of tools and equipment used in some hundred sewage treatment plants within the district of the Interstate Sanitation Commission (N.Y., N.J., Conn.) which extends about fifty miles across and includes New York Harbor and adjacent waters.

Equipment

- Adding Machine
- Alemite or Zerk grease guns for plant equipment
- Barricades
- Blower—Air, portable—gasoline driven
- Brooms—Street, ordinary, industrial type.
- Brushes—
  - Flue
  - Paint and Whitewash
  - Scrubbing and long-handled
  - Wire
- Blocks and Tackle for ½-in. and ¾-in. rope
- Boots—Hip and knee
- Cans—
  - 5 gal. for gasoline, safety type.
  - 5 gal. for kerosene, safety type
  - Rubbish
- Caulking Gun—for glass house windows
- Chain Hoist—one ton capacity
- Concrete Mixer—Portable, gasoline powered
- Dippers
- Electric Drop Light — explosion proof, with extension cord—200 ft.
- Electric Generator — portable, gasoline driven
- Electric Torch Light—1½ or 3 volts
- First Aid Cabinet
- First Aid Emergency Chart (first aid directions)
- Fire Extinguishers
- Fire Pails
- Flags—Danger, for street use
- Flag Tripods
- Flashlights—Hand
- Flood Lights (to operate from portable generator)
- Funnels—Assorted sizes
- Gaskets—Sheet rubber and Vellumoid Gasket Paper
- Gasoline Engine for operating 3/16-in. sewer rods mounted on a two-wheel trailer
- Gloves—Rubber and canvas, work
- Goggles—Safety
- Hydrometers—Battery and Alcohol
- Hose—
  - 2 or 2½-in. for flushing out sewers (with 4 x 2 or 2½-in. reducer)
  - 300 ft. Garden type
  - Spare Hose for chlorinator
  - 20 ft. suction with strainer and 100 ft. discharge hose for use with power operated pump
  - Nozzles—Shut-off type
- Ladder—
  - Extension to 20 ft.
  - Step
- Lanterns—Red, also white globes
- Laboratory equipment as required
- Mop and Handle
- Padlocks
- Paint Sprayer
- Pails—12 qt. heavy galvanized
- Pencil Sharpener
- Picks
- Pumps—2-in.-4-in. portable, self-priming centrifugal, diaphragm or piston gasoline, engine driven
- Rope—½, ¾ and 1-in. and sash cord or clothes line
- Rubber Raincoats, hats and suits
- Safety Equipment—
  - Explosimeter
  - Gas Mask (chlorine)
  - Harness (safety belt) with 25 ft. ¾-in. rope spliced on
  - Oxygen Breathing apparatus (Chemox)
  - Oxygen deficiency indicator
  - Respirator (for paint spraying, dust, etc.)
- Scum Skimmer
- Sludge Sampling Equipment
- Sludge Shredder
- Sprayer—hand, fly
- Squeegees—Floor and windows
- Torches—Bomb type
- Truck—Light, for carrying equipment
- Two-Wheel Hand Truck
- Typewriter
- Vacuum cleaner
- Waste Cans
- Wheel Barrow—Rubber tired
- Wringer Buckets

Garden Implements

- Brush Hooks
- Garden Trowel
- Hedge Clippers
- Hoe
- Hose—
  - Garden type, approximately 300 ft.
  - Nozzles—Shut-off type
- Insect Sprayer
- Lawn Roller
- Mower—
  - Lawn, hand or motor operated
  - Edging
- Pruning Shears
- Rakes—
  - Wood
  - Steel
- Scythe
- Sickle
- Spade
- Sprinklers—Nozzle type

Materials and Supplies

- Alcohol or Anti-freeze.
- Assortment of bolts, nuts, washers, screws, cotter pins, rivets, lock washers, cap screws, stud bolts, etc., stored in jars or cans.
- Bricks—Common.
- Calcium Chloride (for icy pavements).
- Caulking Compound and sewer joint compound.
- Caulking Compounds, Durolite or equal for glass house windows.
- Caulking Yarn.

Cement.
Cement—Asbestos.
Chain—Assorted sizes and lengths.
Chamois Skins.
Cleaning Compound, broiler.
Cleaning Powders—assorted.
Cups—Drinking.
Cutter Wheels—spare.
Disinfectants (CN and others).
Emery Cloth—assorted grades.
Fittings—Brass or iron—assorted sizes.
Flashlight Batteries.
Fuses—Assorted.
Glass.
Graphite.
Grease—For lubrication.
Hose, Nipples and Clamps for garden hose, extra.
Iron and Boiler Cement.
Kerosene.
Lead and Lead Wool.
Light Bulbs.
Measures—Oil, 1 qt. and 1 pt.
Mops.
Nails—Assorted sizes.
Oakum.
Oil for lubrication.
Oil—Rust removing, penetrating.
Packing for pumps.
Paint Remover.
Painters Drop Cloths.
Paints—Turpentine, linseed oil, thinners, etc.
Pipe Joint Compound.
Pipe Stock—depending on system.
Plugs—Rubber Expansion.
Polish—Brass.
Putty.
Rags—Clean and sterilized.
Sand—Stone or gravel.
Sand Paper—Assorted Grades.
Soap.
Solder.
Soldering Paste.
Spare Handles for Hammers, hatchets and axes.
Spare Parts for all Machines and Apparatus.
Sponges.
Steel Wool.
Tape—Friction and electricians.
Thermometers—Assorted.
Toilet Paper.
Towels.
Valve Grinding Compound.
Waste—Wiping.
Wicks—For torches and lanterns.
Wire—Annealed No. 10 and No. 16.

Tools

Axes—spare axe handles.
Awls.
Bars—crow.
Bars—wrecking.
Bit brace and assortment of bits for wood and metal.
Blacksmith's anvil, tools, forge and hand blower.
Bolt stock and dies.
Breast drill and assortment of drills.
Calipers—inside and outside.
Calipers—micrometer.
Caulking tools—water main type (assorted sizes and types).
Chisels—assorted.
Chisels—bull point.
Chisels—cape.
Chisels—cold.
Chisels—diamond point.
Chisels—round nose.
Chisels—assorted—wood.
Chisels—assorted—for air hammer.
"C" Clamps—assorted.
Cotter Pin Puller.
Countersink—assorted for wood or metal.
Cutters—wire.
Cutters—¼-in. bolt.
Dies—assorted for bolt and pipe threading stocks.
Drills—assortment.
Drills—electric portable ⅝-in. for twist drills No. 60 to ⅝-in. with drill press stand mount.
Drills—electric portable ¼-in. for twist drills No. 0 to No. 60.
Drills—hand.
Drills—press, bench type.
Drills—star drills of various sizes.
Extractors—screw, various sizes.
Files—assorted sizes.
Files—flat.
Files—half round.
Files—round.
Files—taper (triangular)
Files—wood rasp.
Fire pot—including metal foot and wrought steel ladle—for use with B and S cast iron pipe.
Flanging tools—for use with copper pipe.
Flaring tools—for use with copper pipe.
Fuse Puller.
Gages—set of shim.
Gages—test for pressure and vacuum.
Glass Cutter.
Grinder—electric or hand—bench type.
Grinder—wheels, coarse, fine and wire brush.
Hacksaw—adjustable frame with extra blades.
Hammers—Ball pein—assorted sizes.
Hammers—Blacksmith's type.
Hammers—Caulking.
Hammers—Claw.
Hammers—Masons.
Hammers—Rubber Mallet.
Hammers—Sledge type—various sizes.
Hatchet.
Jacks—screw or hydraulic—various sizes.
Joint Runner—asbestos, for use with lead joints.
Lathe—metal, 12-in. swing, 24-in. centers.
Lathe tools and appurtenances.
Lead Pot and Ladles.
Levels—Line.
Levels—Spirit—metal frame 18-in.
Line—Mason.
Manhole cover lifting hooks.
Mattock.
Nail Sets—various sizes.
Oil Cans—several types and sizes as required.
Plane—Smooth, bench 7-in.
Pliers—assorted sizes.
Pliers—Diagonal cutting.
Pliers—Gas.
Pliers—Combination slip joint.
Pliers—Needlenose.
Pliers—Wrench.
Packing Hooks.
Packing Tools—assorted.
Pipe Cutter.
Pipe Cutter—wheels (spare).
Pipe Taps.
Pipe Thread Taps (combination) ¼ to 2-in.
Pipe Threading stock with assorted dies.
Pipe Tripod.
Plumb Bob.
Puller—gear set.
Punches—assorted sizes, center, drift.
Putty Knives.
Reamers—Hand, Taper, Pipe, Expansion.
Rules—6-ft. folding.
Saws—Rip, cross cut, compass and keyhole.
Saw Set.
Saw Vise.
Screw Drivers—various sizes.
Screw Pitch Gauge.
Scribers.
Shears—Tinsmiths, straight and curved blades—assorted sizes.
Sewer Rods and attachments 3/16-in. and 5/16-in.—3-ft. lengths for house and main line connections.
Scale Platform.
Sharpening Stone.
Shovels—Square Point, long and short handle.
Shovels—Round Point, long and short handle.
Snake—25-ft. spiral.
Soldering Iron and appurtenances.
Square—steel, large and small.
Stamping Tools—steel, letters and numerals.
Straight Edge—Steel.
Tampers.
Tape—50-ft. steel.
Tar Pot.
Torch—Blow, and gasoline.
Trowels—floats, steel and cork assorted.
Trowels—pointing.
Valve Resetting Tool.
Vises—bench and pipe, portable chain vise and stand.
Voltage Tester.
Wall Scrapers.
Washer or gasket cutter for making own washers.
Welding outfit with appurtenances, goggles and gloves.
Wire stripper.
Wrenches—adjustable—various sizes.
Wrenches—Allen set screw.
Wrenches—Box wrench set.
Wrenches—Hydrant.
Wrenches—Monkey.
Wrenches—Open end—various sizes.
Wrenches—Ratchet—socket set.
Wrenches—Socket—set of various sizes.
Wrenches—Spanner.
Wrenches—Stillson—various sizes.
Wrenches—Torque.
Wrenches—Valve.

Col. Gotaas Decorated Again

Col. Harold B. Gotaas, President of the Institute of Inter-American Affairs, has recently been honored again receiving the Legion of Merit from the United States with a citation for outstanding services in the operation of the cooperative health and sanitation and strategic materials development programs in the Latin American republics. In addition to the Legion of Merit, and the decorations named, Col. Gotaas also recently received the "Cruz de Boyaca" from the government of Colombia.

Col. H. B. Gotaas

Clean Waters

A Motion Picture

The General Electric Co. of Schenectady has completed a technicolor movie titled "Clean Waters," showing various equipment used in modern sewage treatment and its economic advantages to municipalities. This motion picture has been prepared for presentation to the lay public and is excellently done. One of its most interesting features is its diagrammatic explanation of primary and secondary sewage treatment processes. The picture also vividly shows what happens to clean waters when wastes are discharged into them.

Persons interested in bringing the matter of stream pollution abatement to various organizations and the public should contact their nearest representative of the General Electric Co., who will make available a copy of the film. Without doubt, this picture, which has had excellent technical editing both from the standpoint of photography and sanitary engineering, is an outstanding contribution to the program of clean streams. The picture has had the sponsorship of the U.S.P.H.S.

Kepner Heads Colorado Engineers

Dana Kepner has been elected President for 1946 of the Colorado Society of Engineers. Mr. Kepner is well known in the water and sewage works field not only as a representative of many manufacturers of water and sewage works equipment, but also for his activities both in the water works and sewage works associations. In 1939 Mr. Kepner was awarded the Fuller Award for the Rocky Mountain Section of AWWA and in 1945 Kepner was elected Director of the Federation of Sewage Works Associations, as a representative of the Rocky Mountain Sewage Works Assn.

Dana Kepner

DIRECTORY OF STATE SANITARY ENGINEERS

There have been many times when we have received inquiry as to who directs the sanitary engineering activities of the several states. At a time when designing and planning of new water and sewage works is uppermost in our minds, it seems well to print herewith, for the benefit of our readers, the latest list as recorded in the offices of the U. S. Public Health Service. Included in the following list are the Philippine Islands, the territory of Hawaii, Territory of Alaska, and the District of Columbia in addition to the heads of the Sanitary Engineering Divisions of the various State Boards of Health.

STATE SANITARY ENGINEERS

Alabama
Thos. H. Milford, Chief Engr. & Dir.
Bureau of Sanitation
State Dept. of Pub. Health
Montgomery, Alabama

Alaska
R. S. Green, P. A. San. Engr. (R)
Public Health Engng. Div.
Territorial Dept. of Health
Juneau, Alaska

Geo. W. Marx, Director
Div. State San. Engng.
State Board of Health
Phoenix, Arizona

Arkansas
Leon MacDonald, Chief Engineer
Bureau of Sanitation
State Board of Health
Little Rock, Arkansas

California
C. G. Gillespie, Director
Bureau of San. Engng.
State Dept. of Pub. Health
Berkeley, California

Colorado
Vacancy (Director)
Div. of San. Engng.
State Board of Health
Denver, Colorado

Connecticut
W. J. Scott, Director
Bureau of San. Engng.
State Dept. of Health
Hartford, Conn.

Dist. of Columbia
Wm. H. Cary, Director
Div. of Sanitation
District of Col. Health Dept.
Washington, D. C.

Delaware
R. C. Beckett, State Sanitary Engineer
State Board of Health
Dover, Delaware

Florida
David B. Lee, Director
Bureau of Engng.
State Board of Health
Jacksonville, Florida

Georgia
L. M. Clarkson, Chief
Div. of San. Engng.
State Dept. of Pub. Health
Atlanta, Georgia

Hawaii
B. J. McMorrow, San. Engr.
Bureau of Sanitation
Board of Health
Honolulu, Hawaii

Idaho
H. C. Clare, Director
Pub. Health Engng.
State Dept. of Pub. Health
Boise, Idaho

Illinois
C. W. Klassen, Chief
Div. of San. Engng.
State Dept. of Pub. Health
Springfield, Illinois

Indiana
B. A. Poole, Director
Bureau of San. Engng.
State Board of Health
Indianapolis, Indiana

Iowa
A. H. Wieters, Director
Division of Engng.
State Dept. of Health
Des Moines, Iowa

Kansas
Paul Haney, Act. Director
Div. of Sanitation
State Board of Health
Lawrence, Kansas

Kentucky
F. C. Dugan, Director
Bureau of San. Engng.
State Dept. of Health
Louisville, Kentucky

Louisiana
John H. O'Neill, Sanitary Engineer
State Dept. of Health
New Orleans, Louisiana

Maine
J. E. Hale, Act. Chief
Div. of San. Engng.
State Dept. of Health & Welfare
Augusta, Maine

Maryland
George L. Hall, Chief Engr.
State Dept. of Health
Baltimore, Maryland

Massachusetts
Arthur D. Weston, Chief Engr.
Div. of Sanitary Engng.
State Dept. of Pub. Health
Boston, Massachusetts

Michigan
John M. Hepler, Director
Bureau of Engineering
State Dept. of Health
Lansing, Michigan

Minnesota
H. A. Whittaker, Director
Division of Sanitation
State Dept. of Health
Minneapolis, Minnesota

Mississippi
H. A. Kroeze, Director
Bureau of San. Engng.
State Board of Health
Jackson, Mississippi

Missouri
W. S. Johnson, Chief Pub. Health Engr.
State Board of Health
200 Monroe Street
Jefferson City, Missouri

Montana
H. B. Foote, Director
Div. of Water & Sewage
State Dept. of Pub. Health
Helena, Montana

Nebraska
T. A. Filipi, Public Health Engr.
State Dept. of Health
Lincoln, Nebraska

Nevada
W. W. White, State Sanitary Engineer
State Board of Health
Reno, Nevada

New Hampshire
Leonard W. Trager, Director
Div. Sanitary Engng.
State Board of Health
Concord, New Hampshire

New Jersey
H. P. Croft, Chief Engr.
Bureau of Engineering
State Dept. of Health
Trenton, New Jersey

New Mexico
H. Booker, Director
Div. of San. Engng. and Sanitation
State Dept. of Pub. Health
Santa Fe, New Mexico

New York
C. A. Holmquist, Director
Division of Sanitation
State Dept. of Health
Albany, New York

North Carolina
J. M. Jarrett, Director
Div. of San. Engineering
State Board of Health
Raleigh, North Carolina

North Dakota
J. H. Svore, Director
Div. of San. Engng.
State Dept. of Health
Bismarck, North Dakota

Ohio
F. H. Waring, Chief Engr.
Div. of San. Engineering
State Dept. of Health
Columbus, Ohio

Oklahoma
H. J. Darcey, State San. Engr.
Bureau of San. Engng.
State Dept. of Pub. Health
Oklahoma City, Oklahoma

Oregon
C. M. Everts, Jr., State San. Engineer
Div. of San. Engng.
State Board of Health

Pennsylvania
H. E. Moses, Chief Engr.
Bureau of Engng.
State Dept. of Health
Harrisburg, Pennsylvania

Philippine Islands
Joaquin Lopez, San. Engr.
Philippine Health Service
Manila, Philippine Islands

Rhode Island
Walter J. Shea, Acting Chief
Div. of San. Engng.
State Dept. of Health
Providence, Rhode Island

South Carolina
Jas. H. Stevens, State San. Engr.
Div. of San. Engng.
State Board of Health
Columbia, South Carolina

South Dakota
Quentin Graves, Director
Div. of San. Engng.
State Board of Health
Pierre, South Dakota

Tennessee
R. P. Farrell, Director
Div. of Sanitary Engng.
State Dept. of Pub. Health
Nashville, Tennessee

Texas
V. M. Ehlers, Director
Bureau of San. Engng.
State Board of Health
Austin, Texas

Utah
Howard M. Hurst, Act. Dir.
Div. of Pub. Health Engng. & Sanitation
State Board of Health
Salt Lake City, Utah

Vermont
Edward L. Tracy, Director
Div. of San. Engng.
State Board of Health
2 Colchester Avenue
Burlington, Vermont

Virginia
Richard Messer, Director
Sanitary Engineering
State Dept. of Health
Richmond, Virginia

Washington
Roy M. Harris, Chief
Division of Pub. Health Engng.
State Dept. of Health
Seattle, Washington

West Virginia
John B. Harrington, Chief Engineer
Div. of San. Engng.
State Dept. of Health
Charleston, West Virginia

Wisconsin
L. F. Warrick, State Sanitary Engr.
Bureau of San. Engng.
State Board of Health
Madison, Wisconsin

Wyoming
Wm. V. Leonard, State Sanitary Engineer
State Dept. of Pub. Health
Cheyenne, Wyoming

N. J. SEW. WKS. ASSN. 31st MEETING HONORS JOHN DOWNES

330 Hear Papers on Dual Disposal, DDT, Operation, and Planning

New President
L. J. Fontenelli
Supt.
Sewage Treatment
Rahway, N. J.

New Secy.-Treas.
M. S. Kachorsky
Supt.
Sewage Works
Manville, N. J.

MEETING in Trenton, N. J., on Mar. 20-22, the New Jersey Sewage Works Assn. held its 31st annual convention as a testimonial to John R. Downes, charter member of the association and a pioneer in the field of sewage treatment. With a registration of 330, 21 exhibits, 12 papers, a smoker, entertainment, and the "Famous Speechless Dinner," this 31st meeting continued in the tradition of the "oldest sewage works association in the world."

Testimonial to John R. Downes

As Master of Ceremonies for the testimonial to Mr. Downes, the New Jersey S. W. A. called on Francis R. Friel, Cons. Engr. of Philadelphia and Vice President of the Federation of Sewage Works Assns.

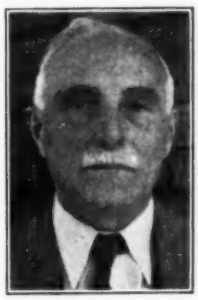
Mr. Friel reviewed the professional career of Mr. Downes, starting with his graduation from Rensselaer Polytechnic Institute in 1907 and his first job in the water works at Harrisburg, Pa. From Harrisburg Downes went to Panama in charge of the Mt. Hope Filter Plant and later became Physiologist in charge of sanitation in the Canal Zone.

In 1914 Mr. Downes came to Plainfield, N. J., where he has been since, first in the local plant and then in the enlarged joint meeting plant.

Among Mr. Downes' professional accomplishments, Mr. Friel cited the following:

1917—Introduced the use of filter alum in sludge drying on beds.

1917—Instrumental in establishment of sewage research division at Rutgers.



Honored

John R. Downes
Supt.
Sewage Works
Plainfield, N. J.
(Kenneth Allen Award and Tokens of Appreciation)

Dr. W. Rudolfs
Chief
Water and Sewage Research
New Brunswick, N. J.
(Honorary Membership in Sewage Wks. Federation)

1925—Introduced the floating cover for sludge digesters.

1927—First operator to use sludge gas for power for blowers.

1938—Introduced the spray dryer for sludge.

A charter member of the N. J. Sew. Wks. Assn., John Downes was one of its organizers and served as its first president. From 1922 to 1945 inclusive, Downes served as secretary of the association and helped it grow from a membership of 80 in 1922 to over 400 at the present time.

In recognition of these outstanding services both to the N. J. Association and to the profession, John R. Downes was presented a scroll, a watch, a billfold, and the Kenneth Allen Award of the Federation of Sewage Works Associations.

Vice-President
Edw. P. Decher
Sec'y
Elizabeth Jt. Meeting
Newark, N. J.

Vice-President
John Struss
Supt.
Sewage Works
N. Wildwood, N. J.

Business Meeting

During the annual business meeting the slate of officers presented by the nominating committee was unanimously elected. Officers for the ensuing year include:

President
Louis J. Fontinelli, Supt.
Rahway Valley Treatment Works
Rahway, N. J.

First Vice President
Leslie West, Chief Engr.
Joint Meeting Sewage Works
Elizabeth, N. J.

Second Vice President
John Struss, Supt.
Sewage Works
North Wildwood, N. J.

*Secretary-Treasurer**
M. Kachorsky, Supt.
Sewage Works
Manville, N. J.

Executive Committee
Frank Van Orden,
Anthony Macri.

*Also Director, Fed. Sew. Wks. Assns.

On with the Show—the War Is Over!
("All High Class Stuff!")

Also during the business meeting of the association, Adm. J. K. Hoskins, Asst. Surgeon General, U. S. Pub. Health Service, and President of the Federation of Sewage Works Associations, presented a certificate of Honorary Membership in the Federation to Dr. Willem Rudolfs, member of the N. J. Sew. Wks. Assn., nominated last year by that association for Honorary Federation Membership. In the presentation, Adm. Hoskins recited the basis of the nomination which reviewed the work of Dr. Rudolfs, not only at the N. J. Agr. Expt. Station at Rutgers, but his work for the Federation, particularly as head of the Research Committee which annually reviews the literature of sewage research and treatment.

DDT as an Insecticide

In the absence of Herman L. Fellton, Sanitarian of the U. S. Public Health Service, his part in the program was taken by **Capt. Lang** also of the USPHS. Capt. Lang, the first of three speakers on "The Use of DDT as an Insecticide," reviewed the history of DDT which was first synthesized in Switzerland in 1938 for its effect on clothes moths. Describing its chemical and physical properties, Capt. Lang said the outstanding property of the insecticide is its effect against a variety of insects when used in small amounts.

DDT has a high stability and therefore a long life as an active agent, acting as both a stomach poison and as a contact poison affecting the central nervous system of the insect. DDT acts slower than some other insecticides but is much surer. It may be administered as a dust, solution, emulsion, or suspension. As a dust DDT is diluted with talc, approx. 10 per cent DDT being used.

Capt. Lang explained the use of DDT as a space spray and as a residual spray. In the former case the intent is to create a dispersion in an enclosed atmosphere so that insects in motion will come in contact with minute particles of the insecticide. In the case of the residual spray it is the intent that the DDT shall adhere to walls and surfaces where the insects may alight, there to come in contact with the chemical.

Because of the somewhat slow action of DDT, other chemicals are mixed with it to increase the knockdown rate of the insecticide, when used as a space spray. Thanite and several Lethanes are used for this purpose.

In the case of house flies, a 5 per cent residual spray is effective for three months. DDT is also effective on the Psychoda fly, on mosquitoes, cock-roaches (the North American variety) and as a larvacide. Certain precautions should be observed. DDT is absorbed through the skin from solutions but not as a powder, or as an emulsion; it is toxic to small animals to some extent, but arsenical insecticides are far more poisonous than DDT.

Leslie West, Chief Engr. Joint Meeting Sewage Treatment Plant, Elizabeth, N. J., reviewed the contributions of DDT to the war and its contributions to sewage treatment plant operation. Explaining how DDT works, Mr. West said that in sewage plants there are two objectives, (1) to reduce breeding and (2) to reduce adult fly populations. For the Psychoda fly, paint or spray the DDT on the walls of the filter to kill the flies almost as fast as they emerge from the larvae stage. DDT can be used on the rock of trickling filters but the carrier is usually poisonous to the filter growth and unless the filter can be rested a short time after applying, the DDT will be washed off before it becomes fully effective on the larvae.

Mr. West cautioned that common sense should be used in the use of DDT and that it should be remembered that DDT will kill useful insects as well as the undesirables. To keep flies out of buildings paint a solution of DDT on the screens, using 1 qt. of the solution (7 oz. to a gallon of kerosene) to 200 sq. feet of screen surface. It is interesting to note that the lethal effect of DDT varies with temperature, flies being killed slower at higher temperatures but mosquitoes being killed faster at the higher temperatures.

Dr. E. J. Hansen, Entomologist, N. J. Agr. Expt. Sta., pointed out that research was still needed on the effect of DDT on insects, and animals, plants, soils, and water. For example, it is known that ½ lb. of DDT per acre of pond surface will kill fish. DDT is good for controlling house fly larvae as well as house flies if the chemical is spread on breeding places, manure piles, etc. DDT should not be used to kill mosquito larvae because it will kill fish.

R. W. Simpson, San Engr., Gilbert Associates, Reading, Pa., speaking from the floor, warned of the fire hazard of space sprays in closed buildings, and told of the success of a fly control program in Denver where garbage cans and city dumps were sprayed with DDT to reduce the fly population and prevent the spread of poliomyelitis. It can not be definitely stated whether or not the incidence of infantile paralysis was reduced but the beneficial effect on reducing house fly density was very marked.

Rutgers Resumes Short School

In the absence of Prof. Harry Lendall, Head, Civil Engineering, Rutgers Univ., Prof. Margen announced the resumption of the Short School for sewage works operators. This course was begun in 1927 and was jointly sponsored by Rutgers, the State Dept. of Health, and the N. J. Sew. Wks. Assn. Since the beginning of the war it has been impossible to hold the two week course. It is being resumed this year on a somewhat different schedule. Beginning April 2, the course is offered on Tuesdays and Fridays of each week until May 3, with classes being held from 9 to 12 and from 1 to 5 each day. Certificates of attendance will be granted to those who attend all classes, and the course of instruction will include plant operation, and laboratory technic.

Comprehensive Planning

Advising his listeners to get a legal planning board for their respective communities, **T. Ledyard Blakeman,** Chief, N. J. Bureau of Planning, said that plans for community development should be so drawn that they would entail no difficulty in the construction of a properly sewered extension.

William D. Jones, Division Engineer, Federal Works Agency, explained the Bureau of Planning of FWA and how it was attempting to stimulate Public Works for the post war years by loaning money for the preparation of public works plans.

In borrowing the money the applicant agrees to repay it when construction is begun, and also to carry through the plans. One-half of the loan for the preparation of the plans is made at the time the agreement is signed, and the other half when the plans are completed. At the present time, the state of New Jersey has had 300 communi-

Programmers

H. W. Peterson, Pres. of Council, Woodbury, N. J. — *H. V. Crawford, Genl. Electric Co., Schenectady, N. Y.* — *John W. Hood, Sup't Treatment, Ridgewood, N. J.* — *C. J. Shepherd, San. Engr., Camp Killmer, N. J.* — *Geo. W. Cameron, Sup't Treatment, Atlantic City, N. J.* — *Walter R. Darby, N. J. Dep't Finance, Trenton, N. J.* — *Chester W. Paulus, Mayor, New Brunswick, N. J.*

ties submit applications (not all for water or sewage plants) and 100 have been approved.

Speaking extemporaneously, **Walter R. Darby,** Director of Local Government, N. J. State Dept. of Taxation and Finance, said he had seen the unfortunate results of planning, particularly with respect to "Financing Sewage Works." Municipalities planning sewers or sewage treatment plants always run into the question of where the money is coming from. Mr. Darby suggests that the solution of this problem will be aided by the employment of a good bonding attorney, whose services will probably more than save his cost by obtaining a better rate on the bonds.

Mr. Darby also said that municipalities should obtain good consulting engineers, and good contractors, and should remember that financing of a project has not been accomplished in its entirety until the bonds are paid off. While not forgetting that sewers are essential to life and health in a community, the planners should also remember that planning is needed as to the ability of the taxpayer to pay both the interest and the amortization.

Local assessments are not so popular now and neither are joint-meetings. Sewer service charges or so-called sewer rental is gaining in popularity because it does not tax vacant land.

Long Chlorine Line Proves Practical

At Atlantic City, N. J., the sewage treatment plant is located on an island 1500 ft. offshore, and **George W. Cameron,** Supt., City Island Sewage Treatment Plant, explained how some 45 tons of chlorine a month are delivered to the island plant.

Federation "Brass"

President
J. K. Hoskins, Chief Engineer, U. S. P. H. S., Washington

Vice-President
F. S. Friel, Consulting Engr., Albright & Friel, Philadelphia

A footbridge connects the island with the shore and it was decided to use a pipe line to carry liquid chlorine from ton containers to the evaporators at the plant. Heavy pipe and pipe fittings, capable of withstanding 250 lb. pressure, was used in the line which had five expansion bends as it was subject to direct sunlight and heat rays.

When the line was installed five years ago, some leaks developed, but these were corrected and no trouble has occured since. In order to transport the liquid that distance it is necessary that the ton containers be kept in a building warmed to 105 deg. F. At this temerature the pressure in the containers is 154 lb. per sq. in., and is high enough to overcome friction losses through the pipe and still deliver the chlorine to the evaporators at proper pressure.

In order to prevent loss of large amounts of chlorine gas should a severe break occur in the line due to storms, a check valve was placed in the line, and this valve is set to operate when ever the rate of chlorine flow reaches 3000 lb. per hour.

Trouble from chlorine taffy was eliminated by placing a trap in the line from the heater to the chlorinator. This trap is 6 ft. high and 8 in. in diameter.

Fundamentals of Biological Oxidation

Tracing the relation and similarity of chemical coagulation and biological clarification, **John W. Hood,** Supt., Sewage Treatment Plant, Ridgewood, N. J., showed that fundamentally certain factors are common to both processes and the same work must be performed by both to bring about the desired results.

The paper by Mr. Hood enumer-

Show Prologue—Unprogrammed

In which Harry Croft, dissatisfied with the professional song leader, decided to take over. With Sam Probasco of Burlington (held by lapel in second picture) they sang Cornell's "Cuyahoga's Waters" and other songs—but, "All High Class Stuff." Second from right, pudgy but nimble "Andy" Radel, New Brunswick operator, volunteering "The Dance of the Butterflies" (or sumpin) with the aid of his jacket. The others ("Madam Bustonobi" and the very clever girl banjoist) are hired performers.

"Gene" Swineheart, Supt. Pottstown, N. J.
"Steve" Whitney Chicago Pump Co.
Geo. H. Boone, Supt. Norristown, N. J.

S. W. Kitson and David I. Gallagher Worthington Pump & Machinery Co. Harrison, N. J.

Madison-Chatham Plant Staff Howard C. Molitor Ass't Supt. Ed. Molitor Supt. Hubert Cannon Operator

John W. Hood Supt. Treatment Works and Albert Faber Comm. Public Wks. Ridgewood, N. J.

Al. Godamski, Ch. Chemist Perth Amboy, N. J.
Ander Christen, Operator Raritan Twshp.
Harry Anderson, Operator Woodbridge Twshp.

ated the additive factors involved in the case of biological oxidation, indicating the environmental requirements required to be satisfied before optimum results can be obtained.

It was shown that failure of chemical means to attain optimum results is due to adversely high pH-alkalinity values. According to Mr. Hood, frontal assault on this problem is both costly and unproductive of desired results. On the other hand, successful and economical coagulation is obtainable by initial downward adjustment of these pH-alkalinity values using various means of pre-carbonation and/or dilution by waters having lower pH-alkalinity values before the introduction of the coagulant.

Biological processes are likewise adversely affected by high pH-alkalinity values which may, in extreme cases, cause failure because the biological population is affected. Mr. Hood cited the work of Carothers (*Water & Sewage Works*, Jan. 1946) in which he, Carothers, reduced the pH of the sewage in the primary tank by allowing a partial digestion to take place at that point, thereby producing CO_2 which lowered the pH of the sewage to a point where good nitrification in the aeration tanks was effected.

Curves showing the changes in pH-alkalinity values in coagulation and biological clarification show the basic similarity of the two systems.

Mr. Hood believes that pH-alkalinity values may be used to advantage in numerous ways by both designers and operators. Preliminary surveys of water supply and sewage values may give a key to proper design and operation in order to produce the best clarification. Studies of these values may also offer a good check on plant performance both over-all and unit by unit.

Mr. Hood concluded from his studies and observations that all biological oxidation processes are basically similar despite the physical dissimilarity of the types of plant. The degree of treatment is a direct product of structural design. Difficulties of correlating the work accomplished in similar plants under comparable loading conditions may be ascribed to disregard of respective pH-alkalinity values. Likewise, plants whose design has been predicated solely on a B.O.D. basis do not necessarily produce the anticipated results. Plants with low pH-alkalinity values show success and vice versa.

Not all factors enumerated by Mr. Hood are subject to control, but in both chemical and biological clarification plants adjustment of pH-alkalinity values, D. O., food, and elemental ratios, substantially improve plant performance.

Existing biological oxidation plants may require adjustment of the physical plant as well as adjustment of chemical conditions. For example a trickling filter that will not de-collcid applied sewage may require a change in stone.

Mr. Hood's final conclusion was that satisfactory performance of new plants will be assured if, in addition to other factors involved, due consideration is given to the vital and basic pH alkalinity value.

New Vice-Pres.
Leslie West Chief Engr. Joint Meeting Elizabeth, N. J.

Arrangements
P. N. Daniels Sup't Sewage Works Trenton, N. J.

High Rate Trickling Filters

In the operation of high rate trickling filters at Camp Kilmer **Clyde J. Shepherd,** Sanitary Engineer at the Camp, was proud to relate that not once since Oct. 194[illegible] when the plant went into operation had the plant been bypassed even though the storm flow reached 2[illegible] mgd. in the plant of 7 mgd. design.

The plant was designed to remove 75 per cent of the suspended solids and 40 per cent of the B.O.D. in the primary treatment. The filters are 125 ft. in diameter and 3½ ft. deep and remove 3000 lb. of B.O.D. per acre ft. per day. Chlorine is added to the effluent and the addi-

Grant Laughlin Chief Engr. Maguetite Filtr. Co. New York

J. F. Boreiszo Corps of Engrs. U.S.A. (On Terminal Leave)

R. C. Beckett Chief Engr. Del. Dept. Health Dover, Del.

Harry J. Krumm City Chemist Water and Sewage Allentown, Pa.

"Andy" Palmer Ass't Sup't Sewage Works Plainfield, N. J.

Wm. R. Lafferty Sup't Sewage Works Lakeland, N. J.

A. J. Beck Chemist S. West Plant Chicago

M. H. Smith
Ass't San. Engr.
and
Ed. T. Roetman
Sanitary Engr.
Viscose Corp.
Marcus Hook, Pa.

Dr. Willem Rudolfs
Chief
Water and Sewage Rsch.
New Brunswick, N. J.
and
J. K. Hoskins
Chief San. Engr.
U. S. P. H. S.
Washington

Fredricks
and
Drane
like
Council President
Peterson's Remarks
on Sewage Works
Financing and
Salaries

"Jake" Van Atta
Vice-Pres.
Ralph B. Carter Co.
New York
and
Sam R. Probasco
City Engr.
Burlington, N. J.

Harold I. Robinson
(Philadelphia)
and
Thos. N. Robinson
(New York)
Pittsburgh Pipe
Cleaner Co.
New York

tion is controlled by an effluent parshall flume. The long outfall sewer acts as a chlorine contact tank.

Pooling troubles were soon evident in the filters. About the same time it was observed that hydrogen sulfide was affecting paint on the nearby structures. An examination of the filter growth showed a heavy infestation of Beggiota alba. It was assumed that the hydrogen sulfide came from the supernatant liquor.

Flooding of the filter with sewage containing 1 ppm. of residual chlorine failed to dislodge the growth. Next the filters were flooded and allowed to become septic with its concomitant digestion of some of the solids on the bed. Samples of the rock indicated that each bed contained 30,000 lb. of solids attached to the rocks. After the septicization was complete the beds were flushed and 60 per cent of the solids removed. Two weeks later heavy sloughing from the filters occurred.

About the same time it was discovered that the primary tanks were leaking and that hydrogen sulfide water was entering the tanks and lines. When these were fixed there was no more trouble from the growth of sulfur bacteria. During the next year it was noted that the heavier the film on the rocks the better the results. It took about a year for the growth on the stone to build up from 2.5 g. to 3.9 g. per Kg. of stone.

Clean Water—A Motion Picture

Not scheduled on the program but shown through the courtesy of the General Electric Co. of Schenectady and H. Vance Crawford, Application Engineer, was the motion picture, "Clean Waters." This was the premier showing of the film which was produced by G. E. for the edification of the lay public on the problems of stream pollution. Sponsored by the U. S. Pub. Health Service, and with adequate technical direction, this technicolor picture which may be obtained for showing from General Electric should do much to explain to the non-technical audience the dangers of pollution as well as show by very adequate animated diagrams, just how a sewage treatment plant works.

"Wheel Horses"

"Ed." Shissler
Sup't
Sewage Works
Haddon Hg'ts, N. J.

H. Van de Vleit
Sup't
Sewage Works
Maywood, N. J.

(Past Presidents Both)

Dual Disposal of Garbage And Sewage

Speaking on the subject of "The Effect of Food Wastes on Sewers and Sewage Treatment Processes," **Morris M. Cohn,** Editor **Sewage Works Engineering,** and Sanitary Engineer of Schnectary, N. Y., reviewed the history of dual disposal since he first proposed it in 1934, and stated that the process was a natural one inasmuch as food wastes and sewage wastes are alike. Both wastes are organic in nature and will decompose in the same manner under the influence of the same type of bacteria. Food wastes, however, need to be ground before they can be added to a sewer, but when ground are of more uniform physical character than are sewage wastes.

In the seven years before the war, some 50,000 household garbage grinding units of one manufacturer were installed in some 300 communities. It is to be expected that other manufacturers will soon be marketing similar devices and greater rates of installation are bound to come. This means that more and more food wastes will be reaching the municipal sewage treatment works.

As to the amount of garbage wastes, Mr. Cohn suggested that national studies indicate approximately 0.5 lb. of garbage per person per day. With 70 to 80 per cent moisture, the actual amount of

L. L. Langford
"P.F.T."
Distr. Mgr.
New York

Sol Seid
Sup't
Treatment Wks.
New Brunswick

R. Ockershausen
Tech. Service
Genl. Chem. Co.
New York

E. T. Roetman
Chief San. Engr.
Viscose Corp.
Marcus Hook, Pa.

Lou Frazza
Johns-Manville
New York

C. W. Sanford
Sup't Jt. Meeting
Elizabeth, N. J.
(40 Yrs. Service)

Erick Hartman
Inertol Co.
New York

solids introduced into the sewage from garbage grinders will be approximately 0.15 lb. per cap. per day or about the same amount as is now received as suspended sewage solids.

For the purpose of rule-of-thumb simplification, Mr. Cohn stated the basic assumption of food waste grinding as follows: (1) the total sewage flow will be increased by one per cent (one gal. per cap. per day); (2) the suspended solids in the mixed flow will be practically doubled; and (3) the B. O. D., may be increased from 15 to 30 per cent.

Universal adoption of this method of garbage disposal will be a long time in the future according to Mr. Cohn's predictions. In the meantime, the installation of a relatively few units (from 100 to 1000 in a city of 100,000 population, for example) will have little effect on the sewage treatment plant or its processes. With 100 garbage grinders the suspended solids would be increased 0.5 per cent, B. O. D. 0.08 per cent, and flow by 500 gallons, or 0.005 per cent. One thousand garbage grinders in the same size city would increase the suspended solids by 5.0 per cent, the B. O. D. by 0.8 per cent and the flow by 0.05 per cent or 5000 gal.

According to the speaker, ground food waste will not shoal in sewers, in any sewers system in which sewage waste will not itself shoal.

Mr. Cohn sees combined disposal as less costly than the collection of garbage by the manual method, and quoted G. J. Schroepfer to the effect that the increased cost of sewage treatment by chemical precipitation at Minneapolis-St. Paul to handle food wastes would amount to only 55 cents per family per year. Mr. Cohn believes that sewer service charges can be extended to garbage grinders at a nominal rate per year, and predicts that garbage grinding in the home will increase but that sewage works superintendents need not worry about increased load if their plants are not now overloaded.

Dr. Willem Rudolfs, Chief, Dept. of Sanitation, Rutgers Univ., considered the various effects of ground garbage on sewage treatment. Confirming Mr. Cohn's statement that the suspended solids from garbage are approximately the same as that from sewage, Dr. Rudolfs noted that the percentage volatile matter in garbage is somewhat higher than that in sewage solids, but the nitrogen content of garbage is but ¼ to 1/10 that of sewage solids.

Dr. Rudolfs presented his comments under several categories.

Effect on Sewers: Information is needed regarding the behavior of ground garbage in flat sewers, but it may be expected that where settling now occurs in sewers, more solids will settle when garbage is added.

Effect on Grit Chambers: Ground garbage settles more rapidly than sewage solids, and the organic content of grit may be expected to increase.

Effect on Settling: Garbage in the sewage will increase the rate of settling. If universal garbage grinding is installed, it may be expected that the sludge volume will increase by 100 per cent, and compaction of the sludge will be improved. The addition of ground garbage will not greatly affect suspended solids removal; the percentage removal may be higher, but since the total suspended solids in the sewage will be greater, the suspended solids in the effluent will likewise be higher. Inasmuch as some of the ground garbage is fibrous there will be a tendency for greater scum formation.

Effect on Chemical Treatment: The addition of ground garbage to sewage will cause only a comparatively small increase in chemical treatment costs, but increases in the amount of sludge must be handled.

Effect on Filters: Addition of ground garbage to sewage will usually result in higher quantities of suspended solids in the effluent from the primary process and therefore more solids will be loaded onto the filters. The B. O. D. in the effluent from the settling tanks will also be higher which means a greater B. O. D. loading on the filters.

Effect on Activated Sludge: As in the case of filters the loading on the activated sludge process will be greater, hence either more air will be required for the process or the B.O.D. of the effluent will be higher.

Effect on Digestion: Garbage is slower to digest, probably because of the lower nitrogen content, but will produce a comparable amount of gas to sewage sludge. A 100 per cent increase in sludge caused by universal garbage grinding will require double the capacity of digestion tanks.

Effect on Sludge Disposal: Quantities of sludge will increase proportionately to the amount of garbage in the sewage. If chemicals are used for dewatering, the amount of chemicals required will likewise be proportional to the amount of garbage present in the sludge. Filter cake will have about the same moisture content as digested sewage sludge.

Effect on Chlorine Demand: The chlorine demand of garbage-sewage mixtures will be higher by the amount of garbage juices caused by the grinding. With 100 per cent garbage added to the sewage, the chlorine demand will increase by 20 to 50 per cent.

Dr. Rudolfs concluded that addition of ground garbage may necessitate more flushing and cleaning of sewers, and an increase in sewage treatment facilities. New plants should consider garbage grinding. While ordinances may delay the installation of garbage grinders, pressure through advertising and good economic conditions will create a demand that will ignore such ordinances, and gradual installation of home garbage grinders will increase.

The Izaak Walton League

Following the discussion of garbage disposal, **Wm. A. Bode,** of Columbia University, spoke on the attitude of the Izaak Walton League. The League is willing to leave technical matters of sewage treatment like garbage disposal to sanitary engineers, but they believe that steps to relieve stream pollution should eliminate all sewage, garbage, and industrial wastes from streams. The League disagrees with the theory that the stream is the third and final stage of sewage treatment or that some streams should be used as sewers while others should be maintained free from pollution. Admitting that the cost of complete treatment might be high, Mr. Bode said that the League favored the Mundt Bill in Congress because it had police powers to enforce pollution abatement.

Financing Sewage Projects

Henry W. Peterson, Pres. of the Council, Woodbury, N. J., told how Woodbury issued bonds, and constructed sewage facilities to eliminate sewage pollution from the Delaware River. This project is financed on a sewer rental basis; each single dwelling paying a minimum charge of $6.00 per year, plus

Speakers

From Left: (1) *Mayor Paulus (New Brunswick).* (2) *Council Pres. Peterson (Woodbury).* (3) *Major M. L. Smith, U.S.P.H.S. Surplus Officer, N. Y. C.* (4) *The Chairman, Ed. Decher, Secy. Elizabeth Joint Meeting, Newark.*

Presentations

(1) *Federation Vice Pres. Friel presenting John R. Downes with Kenneth Allen Award.* (2) *Federation President Hoskins presenting Dr. Rudolfs Honorary Membership Certificate.* (3) *John Downes receives handsome watch as testimonial from N. J. Sewage Wks. Assn.*

⅓ of the amount of billed water. Other rates were developed for buildings, apartments, hotels, theaters, and so forth. This city is to be congratulated for doing its share in cleaning up the Delaware River without waiting for its larger sisters, Philadelphia, Camden, and Gloucester to abate their pollution. Mr. Peterson said that in his opinion, there is no "cost" attached to the monies paid for abating the evils of pollution; the cost is an investment, the best investment any community can make.

In reporting on the results of industrial waste charges at New Brunswick, **Mayor Chester W. Paulus** said that not only had the industrial charges been accepted and paid 100 per cent but increases in plant size were to be jointly financed by the city and industry.

The charges for industrial waste in New Brunswick are: For Flow—$22 per mil. gal.; for Suspended Solids—$5 per ton; for Chlorine Demand—$5 per 100 lb. In 1944 industrial waste charges were $31,000; in 1945, $45,000. Operating expenses for the New Brunswick plant were $96,000 in 1944; and $103,000 in 1945. It is obvious that the industrial waste load is a very appreciable part of the total load on the sewage plant.

Industrial charges vary from $5000 per quarter for one industry to $10 to $15 per quarter for the smallest. It is interesting to note that these charges have made industry more conscious of the operation. In one instance, an industry found that it could reduce its volume charge by 40 per cent by reuse of clear and uncontaminated water.

A Little Barber-Shopping for Victims

In Chair No. 1, Tom Robinson, of Pittsburgh Pipe Cleaner Co. On the shine stand, John Albertson, of N. W. Bowe Engrs. In Chair No. 3, Sam Probasco, Burlington's City Engr.

Procurement of Surplus Property

Maj. M. L. Smith, Sanitarian, USPHS, Office of Procurement of Surplus Property, explained the purpose of offering surplus property at 40 per cent discount from list prices to municipalities and other local government political subdivisions in order to give the property to the public who had originally furnished the money to buy the army material.

Equipment for sewage treatment plants is not plentiful at present but more and more will become available. In order to know what is available, persons interested should write to the nearest regional office of the U. S. Public Health Office.

Exhibitors

The twenty-one exhibitors at the meeting included the following:

American City Magazine
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
DeLaval Steam Turbine Co.
Dorr Co., Inc.
Engineering News-Record.
Fairbanks-Morse & Co.
Flexible Sewer Rod Equip. Co.
Homelite Corp.
Johns-Manville Co.
Limestone Products Corp.
Link-Belt Co.
Mine Safety Appliances Co.
Public Works Magazine
Pittsburgh Pipe Cleaner Co.
Rockwell Mfg. Co.
(Pittsburgh-Equitable Meter & Nordstrom Valve Divisions)
Sewage Works Engineering
Wailes-Dove-Hermiston Corp.
Wallace & Tiernan Co., Inc.
Water & Sewage Works

California Adopts Resolution Against Disposal of Raw Sewage

On March 11 this year the State Board of Health of the state of California adopted a resolution that henceforth the Board will prohibit the issuance of permits for the disposal of raw sewage not only into San Francisco Bay, but into all waters of the state, and henceforth no permit shall be issued by the State Board of Public Health for the disposal of raw or untreated sewage or industrial waste such that the waste may be taken up by the waters of the state.

Furthermore, the Board resolved that all permits heretofore issued for the disposal of raw, untreated sewage into any water of the state shall be revoked on January 1, 1947. It is also noted that the return of raw or digested sludge, or of comminuted sewage solids into the effluent outfall, or similar operations shall not be considered to constitute sewage treatment.

At the same time that the above resolution was adopted, the Board of Health adopted another resolution to the effect that the Department shall review and investigate the status of sewage disposal systems covered by permits with a view to recommending suspension or modification of permits whose continuance is not warranted by the facts. In short, it appears that the state of California is determined to clean up its streams by causing the cessation of the disposal of raw sewage without sewage treatment into the waters of the state, and by improving or extending sewage treatment plants already obsolete or inadequate.

The 1946 legislature enacted a ninety-million dollar bill whose purpose was to place the correction of faulty sewage disposal in a priority position to receive state funds from municipal projects.

A USEFUL "ALL PURPOSE" PIPE CHART

By

W. F. SCHAPHORST, M.E.

NEWARK, N. J.

ENGINEERS and operators often want to know certain things about pipe, and they want to know quickly; perhaps the cubic feet of liquid or gas flowing through the pipe per minute, the gallons per minute, the pounds of water per minute, the velocity of flow, or the exact internal diameter of the pipe regardless of its standard.

All of these quantities are more or less dependent upon each other, the important question usually being the true size of the pipe. Since pipe sizes vary as they do, standard pipe not being exact in internal diameter and extra heavy pipe being different also, it is frequently necessary to search through tables and make more or less lengthy calculations before arriving at the result. And then, after a result is arrived at, one is not always certain that the answer is correct.

Note Three Lines in Column A

Here is a chart that takes care of most of these matters in a decidedly simple way. The best way to explain the method of application of the chart is to give a problem. First, it will be observed that there are three sets of figures given in connection with the extreme left hand column, which is designated as column A. The first column of figures at the left marked "1 standard" gives the actual internal diameter of standard pipe. This column shows, for example, that the internal diameter of a 1-in. standard pipe is somewhat greater than 1 in. because the column of figures marked "2 Exact" gives the exact diameter. Thus, if we have a pipe the internal diameter of which is exactly 2 in., as used in the problem which is cited below, we use this column of figures. The next column of figures, marked "3 Extra Heavy," gives the actual internal diameter of a 1-in. extra heavy pipe as less than 1 in.

Solving a Problem

Now let us apply the chart to a problem, as follows: How much water is passing through a pipe having an internal diameter of exactly 2 in., the velocity of the water being 2 ft. per sec.?

Locate the 2 in column A over the word "exact" and from its point of intersection run a straight line through the 2 ft. per sec. in column C as shown by the slanted dotted line. This straight line intersects column B. From the point of intersection in column B run a straight line over to the identical point in column G, also as shown by the dotted line. The intersection of this perfectly horizontal line from column B to column G gives answers simultaneously in the three columns D, E, and G. It shows that according to column D, 2.6 cu. ft. per min. as flowing through the pipe. Column E shows that the volume of flow amounts to 19.5 gal. per min. And column F tells us that if it is water, the weight of that water is about 165 lb. per min.

It is evident now, on studying the chart, that if the pipe were a 2-in. standard pipe instead of being exactly 2 in., the horizontal line from column B to column G would be slightly lower and the three quantities in column D, E, and F would be slightly greater. On the other hand, it is evident that if a 2-in. extra heavy pipe were used instead of a 2-in. exact, the horizontal line from column B to G would be raised slightly above its shown position and the three quantities in columns D, E, and F would therefore be slightly less.

Working the Scales Backwards

Inversely, if any quantity in columns D, E, and F is known and it is desired to determine the velocity per second of flow through the pipe, this same chart can be used with equal ease. First run the horizontal line through the known point in D, E, or F, and then through the located point in column B run a straight line from the known pipe diameter and the intersection with column C immediately gives the velocity of the liquid in feet per second.

Or if you wish to select a pipe size, knowing any one of the quantities in D, E, or F, and having decided upon the velocity of flow, it is perfectly evident what to do.

Use as a Conversion Chart

At the same time it will be observed that this chart can be conveniently employed as a conversion chart. For example, how many gallons in 2.6 cu. ft.? The dotted horizontal line already drawn shows that the answer is about 19.5 gal., which is also equivalent to about 165 lb. of water. At the same time this chart gives a visual demonstration of the relationship between pipe sizes—standard, exact, and extra heavy. By using this chart one can quickly "read off" the internal diameter of a standard or extra heavy pipe.

The range of this chart is great enough to take care of almost any problem one may encounter. The standard pipe sizes range from ⅛ in. to 15 in., and the velocities from 0.3 to 30 ft. per second.

In the event that the liquid is other than water, multiply the weight of water by the density or specific gravity of the liquid and you then have the weight of the desired liquid. Thus, for example, if it is an oil having a specific gravity of 0.9 we would have in the above problem $165 \times 0.9 = 148.8$ pounds of oil.

Formulas

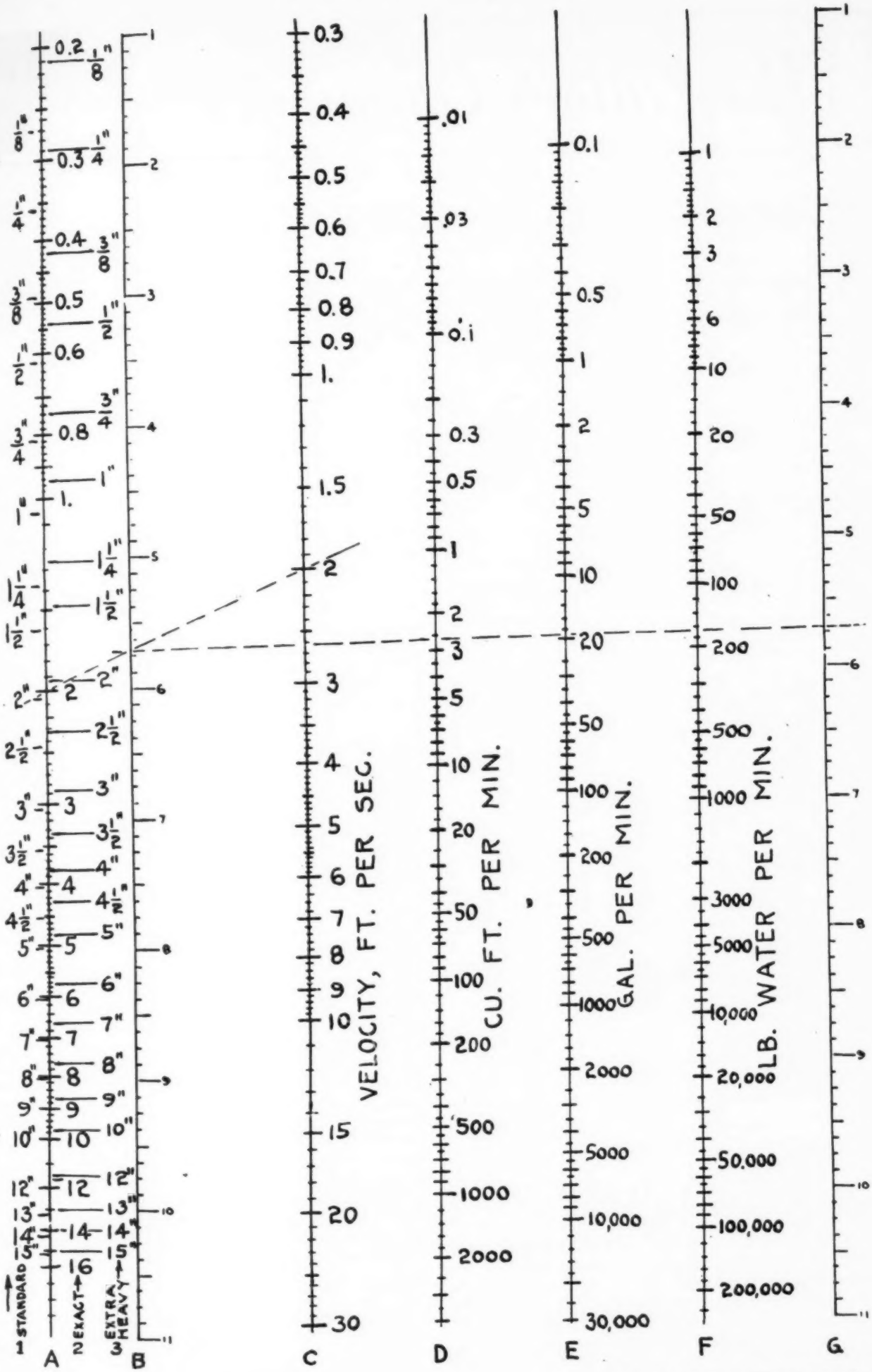
And finally, should one prefer to use formulas rather than this chart either for solving the problem directly or for checking the results taken from the chart, here are the formulas on which the chart is based:

$$Q = 2.45\ d^2\ V$$

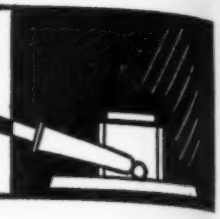
where Q = gallons per minute;
d = internal diameter of pipe, inches;
V = velocity of liquid, feet per second.

Cu. ft. per min. $= 0.327\ d^2\ V$

Lb. water per min. $= 20.4\ d^2\ V$


1 STANDARD
2 EXACT
3 EXTRA HEAVY
A
B
C
D
E
F
G
VELOCITY, FT. PER SEC.
CU. FT. PER MIN.
GAL. PER MIN.
LB. WATER PER MIN.

The Editor's Comments



The following was written for this page awhile back, but for one or another reason its publication has been prevented until now, when it becomes especially timely.

Last month the New Jersey Sewage Works Association's 31st annual meeting in Trenton was dubbed the John R. Downes Testimonial Meeting as a special tribute to the man who played so large a part in the organization and early struggles of America's first sewage works association, and in making the organization click as its first president, and, thereafter, for the number of years that he served the association as its Secretary and Editor.

At the Testimonial Meeting, reported elsewhere in this same issue, Downes was eulogized and presented with gifts of appreciation from the Association and the Kenneth Allen Award of the Sewage Works Federation. Following on the heels of the recounting of John Downes' several achievements in the technical realm, it seemed only fair to bring to light, and to the attention of his associates and admirers, one of his little known talents—that of a humorist with a touch of the clairvoyant.

To this end what proved to be our "ace-in-the-hole" editorial was brought forth and offered for the amusement of the audience and the surprise of many who little suspected that John R. ever possessed the combined talents of the clairvoyant and the humorist which are revealed in his—

"Oh—Whatz-a-Use!"

"Oh—Whatz-a-Use!"

The other day we picked up the Sunday paper and in perusing the ads found one of the big department stores to be featuring "Flush-a-way" diapers for babies. We imagine that these cellulose didies for the nation's young hopefuls are not new, but we haven't seen them featured before in newspaper ads. Seeing this ad brought to mind what we considered a real gem in the nature of "one operator's lament" which was penned by one of America's pioneer veteran sewage works' operators several years back when the use of sanitary napkins made of cellulose had first become widely advertised to the general public and popularized amongst the fair sex.

The operator who penned his lament at that time when just one more problem had been thrust upon sewage plant operators, having fly breeding trickling filters and sludge digesters that operated upside down (seemingly by preference), was John R. Downes, Supt. of the Joint Sewage Treatment Works of Plainfield, Dunellen and Bound Brook, N. J. Although the author did not favor us with a copy of his masterpiece, a mutual friend did. We thoroughly enjoyed its reading and filed it away for future reference. Then, immediately our eye fell upon the ad on "Flush-a-way" didies for the baby, we recalled Downes' lament of an operator. Having located it—its paper now a bit yellowed with age—and having read it again, we are convinced that it deserves permanent recording on this page. Therefore, we now give it to you.

OH—WHATZ-A-USE!
—OR, WHY PLANT OPERATORS GO MAD
by "J. R. D."

We just thought that we had this man's game licked; what with screens and California ragpickers and such to take out the towels and underclothes and everything. And with steam-heated apartments for the bugs to digest the sludge in, and solariums to dry it in, and our old friend Chlorine to knock the film off the filter stones so as the pesky filter flies' larvae would have nothing to dig their toes into and hold on, and would be washed away like our sins; when along comes a bozo with an advertising campaign, and an idea, to save the beautiful, and delicate, and hypersensitive, and supermodest damsel from the necessity of saying what she means; and all she has to do is to say "koto" to the drug clerk and dash off with a mysterious wrapped bundle under her arm like a bloomin' bootlegger's client.

And then she doesn't have to hide it, or bury it, or burn it, or throw it over somebody else's fence, but just throw it in the toilet and pull the chain and that's all there is to it unless the man of the house has to pay the plumber ten bucks to hook it out again. . . .

ONLY, the toilet connects with a pipe and the pipe with a plant, and at the plant the operator goes kookoo because in every 10,000 persons there are enough of these delicate dames to send down 1,000 "kotos" per day. And they escape the screens and the ragpickers, because by that time they are finely divided cellulose, and cause the pH to drop, and give the steam-heated bugs indigestion, and get into the filters and form a toe-hold for the larvae, which no chlorine can wash out. . . And, the psychoda live happy ever after. . . .

AND, FURTHER, it won't be long until the family clothes line may no longer herald the new-born babe to the town, because they will use "koto" didies and then throw them also down the sewer (the didies, not the babies), and with a birth rate of ten per 1,000 even, you get another 1,000 "kotos" of cellulose per day from your 10,000 population. Figure it out for yourself, I hope that we can find a tin-eating bacteria before people get to discarding their old cars for the newer air-flivvers which are descending upon us, 'cause sure as preachin', old cars are going to be thrown down the sewer also some day.—J. R. D.

We would say that "J. R. D." proved himself to be more than a humorist "lamenteer," for his closing paragraph, penned several years back, brands him also as something of a crystal-ball gazer.

L. H. Enslow

SOLVED

TOUGH SEWAGE PROBLEM

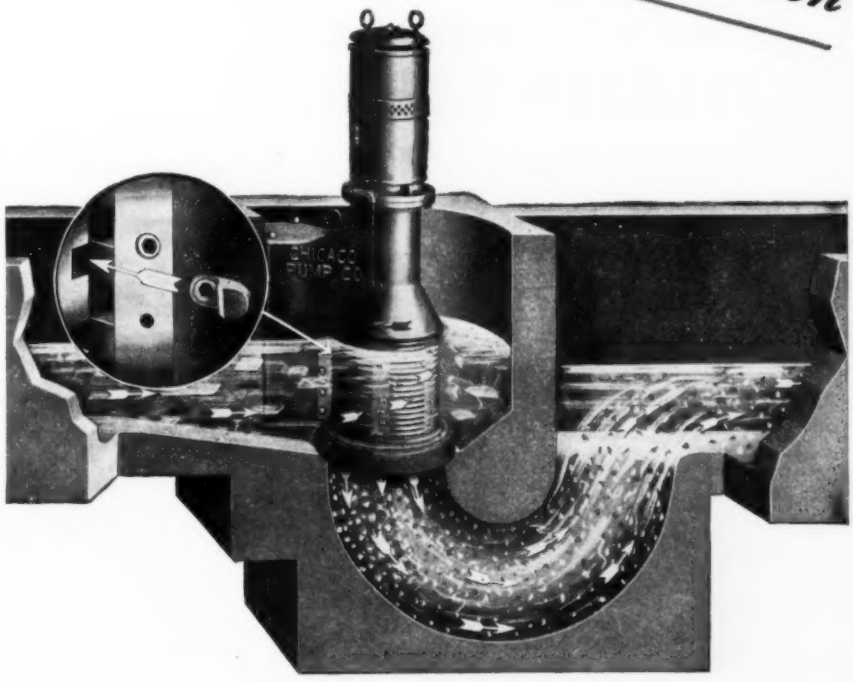
SCREENINGS HANDLING AND DISPOSAL

.....through intensive engineering application

PROVED BY TEN YEARS SERVICE

Comminutors eliminate screenings handling and disposal, the worst nuisance in sewage treatment, by automatically screening and cutting sewage solids under water. No raking of screens and hauling, burial, incineration, or feeding screenings to a grinding mechanism. Eliminate health menace from handling screenings.

Comminutors are easily adapted to existing plants. Over 1,200 installed. Ask for Bulletin 185.



Comminutor installed in a basin forming part of the raw sewage channel. Sewage solids are sheared by cutters on the revolving drum. The small particles pass through the drum slots with the sewage liquor, out the open bottom and back into the downstream channel discharging into the primary tank, where they settle and are pumped to the digester.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

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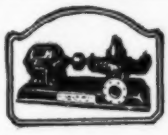

Flush-Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs, Water Seal Pumping Units, Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

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Eliminate waste—streamline your feeding cost figures. Omega "Loss-in-Weight" Type Feeder, with an accuracy of better than 1%, is the most accurate type of chemical dry feeder made. It weighs, feeds and records! Automatic alarm devices safeguard proper operation.

The Omega "Loss-in-Weight" successfully handles any dry material, including Ferrisul and similar hygroscopic materials; available in sizes for feeding ½ lb. to 5,000 lbs. per hour. Feeding action is steady, accurate and continuous, yet instantly responsive . . . without lag or over-run . . . to adjustments made manually or by automatic proportional control devices.

Write for descriptive bulletin and complete information.

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Solution Feeders	Lime Slaking Equipment
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MEETINGS SCHEDULED:

May 6-10—ST. LOUIS, MO. (Exhibits & Technical Meetings in Auditorium). (Accommodations in 12 Hotels) **American Water Works Conference.** (Annual Meeting). Executive Secretary, Harry E. Jordan, 500 Fifth Ave., New York 18, N. Y.

May 16—BRIDGEPORT, CONN.
New England Water Works Association. (Monthly Meeting). Sec'y, W. C. Conroy, 609 Statler Bldg. Boston, Mass.

May 16-17—BALTIMORE, MD. (Hotel Lord Baltimore)
Maryland-Delaware Water & Sewage Ass'n. Sec'y, Miss E. V. Gipe, 2411 N. Charles St., Baltimore, Md.

May 17—GREENWICH, CONN. (Pickwick Arms)
New England Sewage Works Association. Sec'y-Treas., Walter E. Merrill, State Dept. of Health, 511A State House, Boston, Mass.

May 23-24—CORVALIS, ORE. (Gearhart Hotel)
Pacific Northwest Section A.W.W.A. Sec'y, Fred Merryfield, Oregon State College, Corvalis, Ore.

May 24-25—UTICA, N. Y. (Hotel Hamilton)
New York State Sewage Works Association. Act'g Sec'y, A. W. Eustance, State Dept. of Health, Middletown, N. Y.

June 9-11—MONTEREY, CALIF.
California Sewage Association. Sec'y-Treas., Harold H. Jeffrey, 112 City Hall, Sacramento 14, Calif.

June 12—LEWISTON, ME.
Maine Water Utilities Association. Earle A. Tarr, Supt. Water Dist. Winthrop, Me.

June 13-14—LAFAYETTE, IND. (Purdue University)
Central States Sewage Works Assn. Sec'y-Treas., J. G. Mackin, Route 4, Madison, Wis.

June 19—MANCHESTER, VT. (Equinox House)
New England Water Works Association. (Annual Outing). Sec'y, W. C. Conroy, 609 Statler Bldg., Boston, Mass.

June 20-21—AKRON, O. (Mayflower Hotel)
Ohio Conference on Sewage Treatment. Sec'y-Treas., L. B. Barnes, 441 So. Prospect St., Bowling Green, Ohio.

June 28—LITTLE FALLS, N. J.
New Jersey Section A.W.W.A. (Summer Meeting) Sec'y, C. B. Tygert, Box 178, Newark, N. J.

Aug. 14—WOODLAND, ME.
Maine Water Utilities Association. Sec'y, Earle A. Tarr, Supt. Water District, Winthrop, Me.

Aug. 26-28—STATE COLLEGE, PENNA.
Pennsylvania Water Works Operators, Association. Sec'y-Treas., I. M. Glace, 1001 North Front St., Harrisburg, Pa.

Aug. 28-30—STATE COLLEGE, PENNA. (Nittany Lion Inn)
Pennsylvania Sewage Works Asso. Sec'y-Treas., Bernard S. Bush, Penna. Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Sept. 9-11—SAVANNAH, GA. (DeSoto Hotel)
Southeastern Section A.W.W.A. Sec'y B. P. Rice, Healey Bldg., Atlanta 3, Ga.

Sept. 17-20—POLAND SPRING, ME. (Poland Spring House)
New England Water Works Assn. (Annual Meeting). Sec'y, W. C. Conroy, 609 Statler Bldg., Boston, Mass. (On Sept. 16, a pre-convention get-together will be held in the evening.)

Sept. 18-20—TRAVERSE CITY, MICH. (Park Place Hotel)
Michigan Section A.W.W.A. and Conference on Water Purification. (Joint Conference). Sec'y-Treas., R. J. Faust, Michigan Dept. of Health, Lansing, Mich.

Oct. 7-9—TORONTO, CANADA (Royal York Hotel)
Federation of Sewage Works Assns. Exec.-Sec'y, W. H. Wisely, 625 Illinois Bldg., Champaign, Ill.

Oct. 9-11—COLUMBUS O. (Hotels Fort Hayes & Chittenden)
Ohio Section A.W.W.A. Sec'y-Treas., F. P. Fischer, 811 Perry Payne Bldg., Cleveland, O.

Oct. 14-17—GALVESTON, TEXAS
Southwest Section A.W.W.A. Sec'y-Treas., Leslie A. Jackson, Robinson Memorial Auditorium, Little Rock, Ark.

PIPE LINING

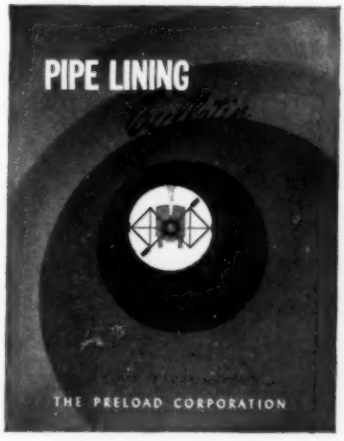
THE MODERN WAY—WITH THE AUTOMATIC PRELOAD CEMENT LINING AND TROWELING MACHINE FOR LINES 30" DIAMETER AND LARGER.

YOUR PIPE LINES ARE THE LIFE LINES OF YOUR CITY—

PROTECT THEM

The vast financial loss, resulting from the rapid capacity reduction of unlined pipe systems, is a matter of major importance to the water works industry. The cleaning and cement lining of pipe lines is not only economically sound, but is usually a self liquidating investment that forestalls the capital investment in new pipe lines for many years in the future. The original carrying capacity of pipe lines is restored and in many instances exceeded by scientific cleaning and mechanical cement lining.

The complete operation of rehabilitating old, clogged or tuberculated pipe lines 30 inches in diameter and larger is as follows: First, a Pitometer or flow capacity survey of the existing line is run to determine the Williams and Hazen Coefficient or "C" Value. Second, the line is then thoroughly cleaned with modern hydraulically operated pipe cleaning equipment. Third, bad joints, connections and leaks are repaired. Fourth, all interior pipe connections and manhole openings are covered with shields and the interior pipe surface otherwise finally prepared for lining. Fifth, the cement mortar lining is mechanically applied. Sixth, after proper curing, the line is put into operation and another Pitometer survey run to determine the resulting "C" Value or increased carrying capacity.



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Bulletin

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Manual de
INGENIERIA SANITARIA

1946

JUST RELEASED
for the
LATIN AMERICAN MARKET
First Annual Edition

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CULTIVATE THIS EXPORT MARKET

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Manual de INGENIERIA SANITARIA is designed to serve as a practical Reference and Data book for the men in Latin America charged with the problems of water supply and sanitation. It is printed in Spanish and offers access to one of greatest potential markets in the world today. The Manual is comparable to the English edition of the Reference and Data issue of Water & Sewage works. It is a handbook of informative data and a buyers' guide.

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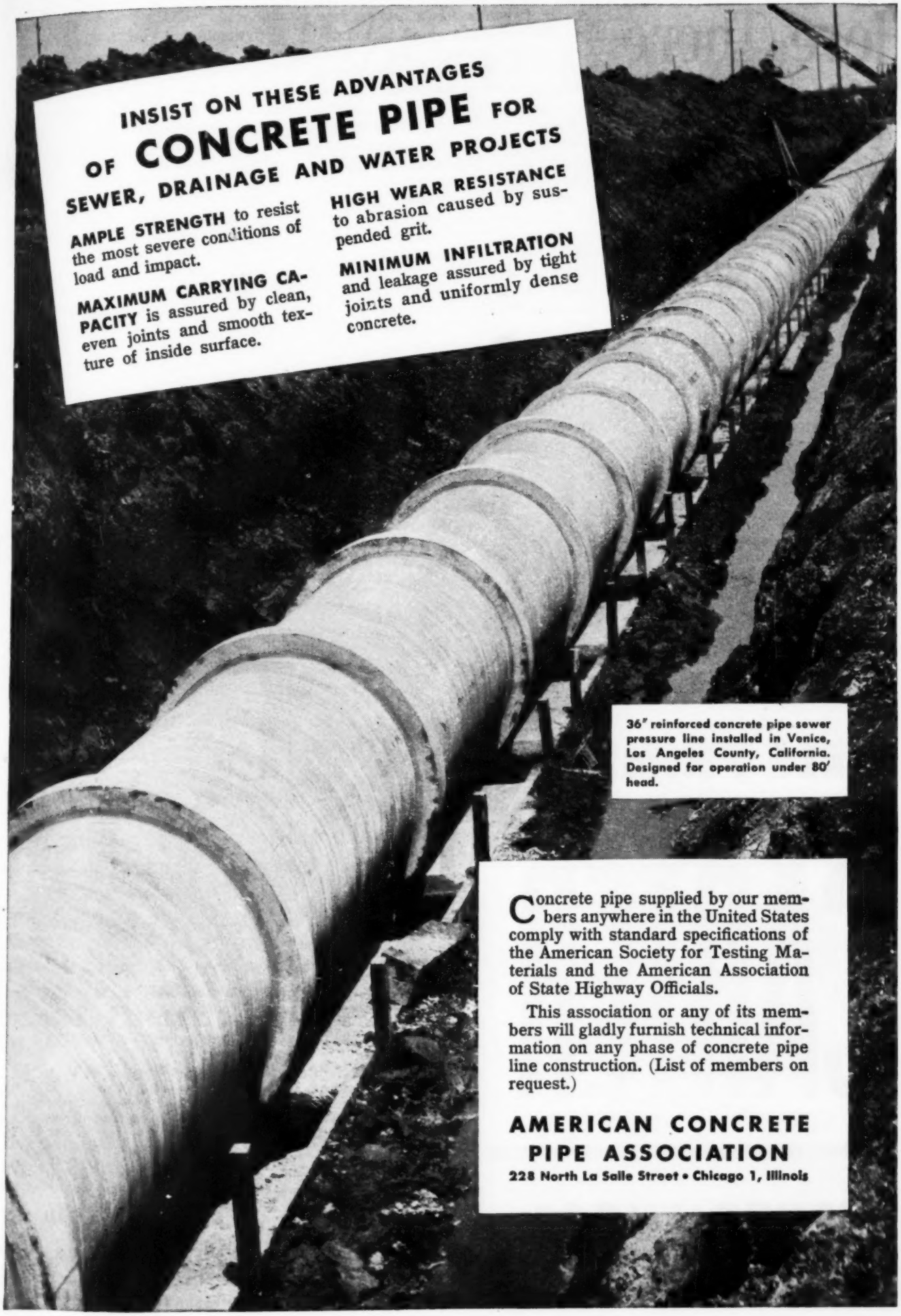


INSIST ON THESE ADVANTAGES OF CONCRETE PIPE FOR SEWER, DRAINAGE AND WATER PROJECTS

AMPLE STRENGTH to resist the most severe conditions of load and impact.

MAXIMUM CARRYING CAPACITY is assured by clean, even joints and smooth texture of inside surface.

HIGH WEAR RESISTANCE to abrasion caused by suspended grit.

MINIMUM INFILTRATION and leakage assured by tight joints and uniformly dense concrete.

36" reinforced concrete pipe sewer pressure line installed in Venice, Los Angeles County, California. Designed for operation under 80' head.

Concrete pipe supplied by our members anywhere in the United States comply with standard specifications of the American Society for Testing Materials and the American Association of State Highway Officials.

This association or any of its members will gladly furnish technical information on any phase of concrete pipe line construction. (List of members on request.)

AMERICAN CONCRETE PIPE ASSOCIATION

228 North La Salle Street • Chicago 1, Illinois

Here and There with Doc Symons

Need I remind you again that this is the Reference and Data issue of *Water & Sewage Works* and that to have a complete Reference and Data File you will also need the June issue of 1945 and the June issue of 1944. You might hang on to the June issues of 1943, '42, and '41 as well because there are a few reference articles in those issues that have not been repeated since. You'll find them indexed in this issue, however.

I can't believe he's gone: Less than three months ago I introduced A. S. "Art" Bedell to the N.Y.S.S. W.A. annual meeting lunch and said "Without Art no president of this organization could ever conduct a meeting." Those men who had preceded me in the chair knew how truly I spoke. Those men yet to preside over that organization may see a new secretary at their side, for Art Bedell is gone, but they and the new secretary will still realize that what I said will be true for a long time to come. For although Art Bedell has passed on, his spirit will continue to guide the destinies of the New York State Sewage Works Assn.

No man can die without leaving his imprint on an organization, if in his life he gave his all to foster the growth and development of that organization. Such a man was "Art" Bedell.

It's hard to impersonally eulogize a man who was your friend. The words well up but all one says is "I can't believe he's gone."

Thought some of you, who have been wondering how this column is coming with its campaign for the adoption of the metric system, would like to know that the Standards Council of the American Standards Association has actually appointed a committee to study the use of metric units in standards.

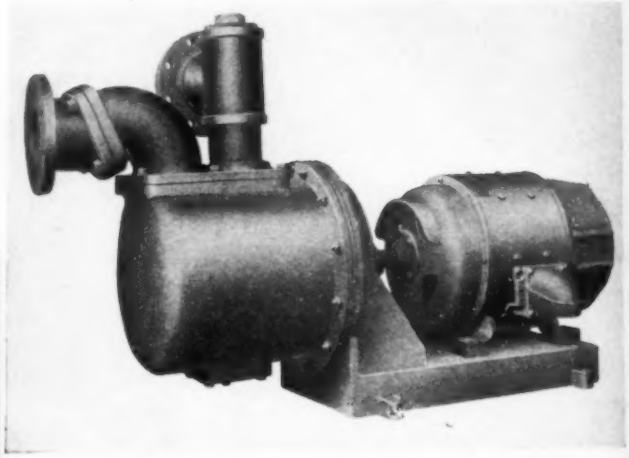
* * *

Wendell LaDue, philosophizing on public relations at the New Jersey Sect. meeting, said, "All of us want a little recognition." How right he is, even this columnist beamed when Bill Denise's boys from Rochester said, "We always turn to the back of your magazine to see what you have to say." Yes, sir, I beamed, but at the same time I wondered if those same fellows ever read any of the other "stuff" I write for the back of the book. Up to now I haven't had the nerve to change the somewhat formal style of the announcements and manufacturers' news, but I sometimes let myself go on the Literature and Catalog Reviews. Would it be indecent of me to suggest that

SELF PRIMING

CARTER

CENTRIFUGAL PUMPS



If efficiency, low maintenance costs, and the ability to prime and reprime are what you demand in a pumping unit, the recently developed CARTER co-axial design is a guaranteed solution.

Nowhere else will you find a pump with such outstanding ability. Actual tests proved this type to out-pump competitive models by more than 20%. This tremendous water moving capacity, plus the ability to prime and reprime in as little as fifteen seconds, together with the elimination of trick weights or flapper valves, gives you 100% water insurance with practically no attention.

• *Write for Bulletin No. 4310.*

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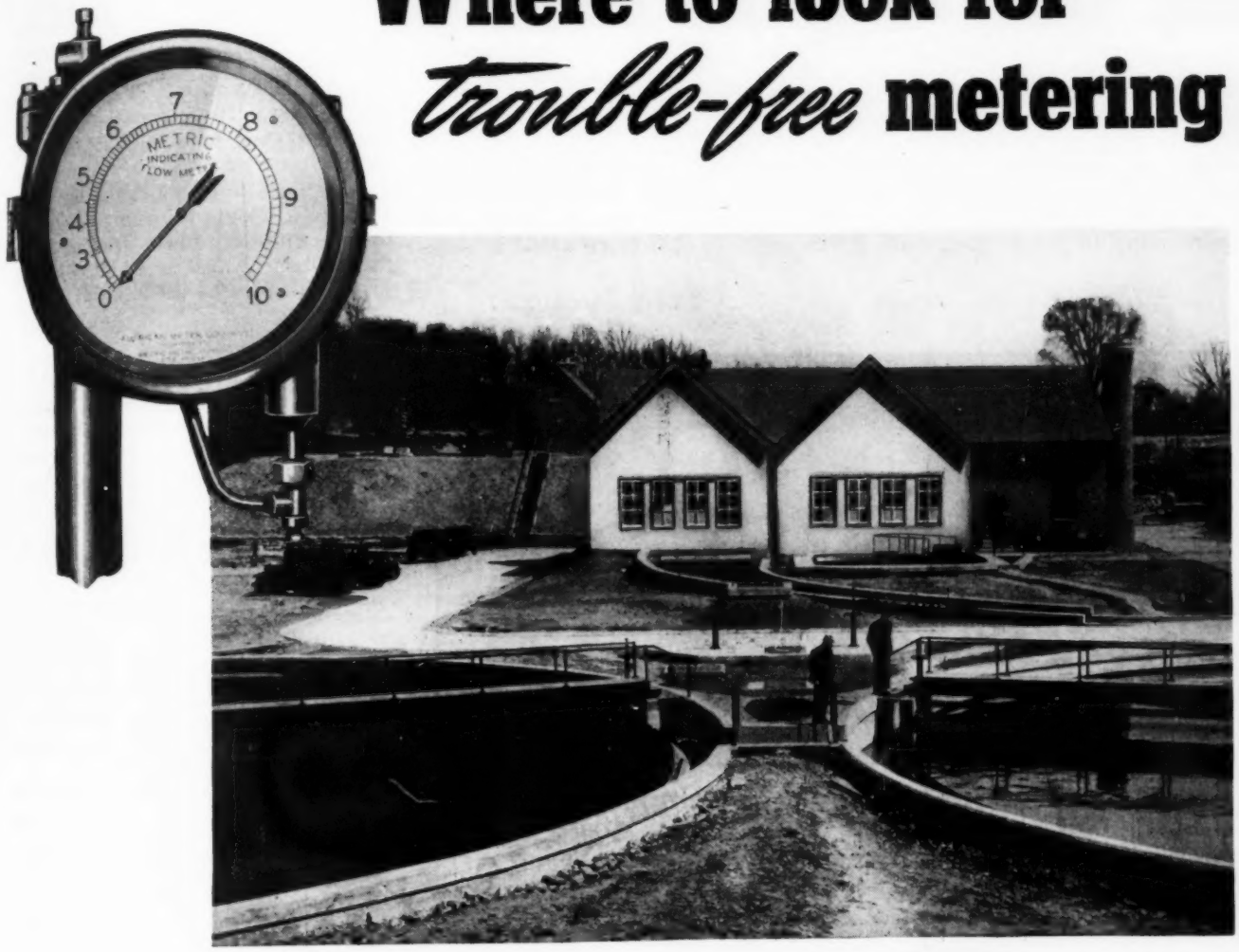
Where to look for *trouble-free* metering



• • • Simplicity of basic design is a characteristic of **American** meters in both displacement metering of sewage gas and orifice measurement of gases and liquids.

In orifice metering, whether by indicating, recording or integrating instruments, you will find fewer moving parts to wear and get out of adjustment, and every provision for easier inspection. These meters are serving in not only the sewage field and the most modern process industries plants in the country, but in the remote parts of the world where ruggedness and ease of maintenance are of even weightier consequence.

In the field of displacement metering of sewage gas, the **American** Ironcase Meter with its rugged one-piece body eliminating gaskets and internal leaks, its full-bellows diaphragm and other features, is giving long years of uninterrupted service.

For consistent trouble-free metering, look to **American** simplicity of design.

Descriptive catalogs are available on request.

2186

AMERICAN
METER COMPANY
INCORPORATED (ESTABLISHED 1836)
METRIC METAL WORKS • ERIE, PA.

you look them over? You'll find them in a somewhat lighter vein, but written to inform you in a friendly and informal manner—I hope, I hope, I hope!

* * *

My Apologies—And How! Boy! Do I owe Bob Mowry an apology. Not only do I spell his name wrong when I announce that he won the Here and There Golf Cup last year but then I fail to produce the cup. You're going to get it, Bob, even if "Smoke" Clement does say that you four fellows tied for the score.—By the way, all of you golfers, don't forget the Here and There Golf Contest for 1946. See this column in the December 1945 issue for the rules of the contest and then send me your score.

* * *

When this magazine decided to change its name starting with the January issue of this year, it was to be expected that there would be some comment. Sure enough, we found this in *Tide Magazine* of Feb. 22, to wit:

"Misunderstood — *Water Works & Sewerage*, a Gillette publication emanating from Chicago, changed its name last month to *Water & Sewage Works*. It seems the experts have wakened to some unfortunate connotations of *sewerage*. Too many of the uninitiated mistake the word for its scatological cognate—sewage, or the material itself—rather than the esoteric ways in which experts have to dispose of it."

* * *

With all of this talk about sanitation in Latin America, one shouldn't forget Ed Cleary's story about some natives down that way who have squatted so long behind the mesquite bush that they couldn't function when they sat in a privy. Seems they'll need some basic education.

* * *

On more than one occasion I have been taken to task for the "lousy" pictures I take at conventions. Now, therefore, hereafter, when I get a particularly good shot, it will be printed here in the column. For example, here's a portrait of a man with a healthy tan from a month's vacation in Florida this spring. How's this one J.V.A.?

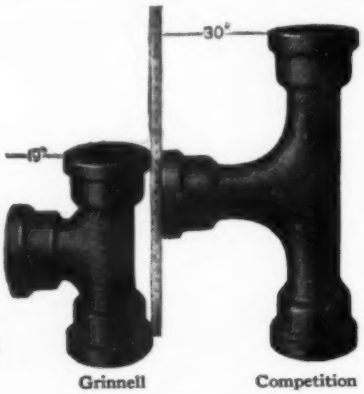
* * *

A couple of years ago, I was taken severely to task for editorializing in this column (griping, my critic called it) and after consulting my college chum, Homer Wisely, I decided to keep this column full of just good clean fun, or as they say in New Jersey, "All High Class Stuff."

Perhaps some of my readers will wonder, then, why last month I brought up the matter of clubroom entertainment at conventions. Well, I do want to say just one more word about it and then back to the "corn." Since last writing I've had the opportunity to observe the clubroom in action, and while I still think it has a number of advantages, I don't believe it will work out unless these conditions are met. (1) A large

SAME USE...

But What a Difference In Size and Weight



	Grinnell		Competition	
	Weight	Run from bell to bell	Weight	Run from bell to bell
4"	96 lbs.	11 in.	128 lbs.	22 in.
6"	147 lbs.	13½ in.	200 lbs.	24 in.
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10"	325 lbs.	19 in.	395 lbs.	28 in.
12"	417 lbs.	21½ in.	512 lbs.	30 in.

Choose Grinnell Socket Fittings

The compact design of Grinnell Socket Fittings does make a lot of difference in actual use—and you'll like that difference! They are easier to handle, fit neatly into close quarters, and speed installations. Friction loss is not increased.

Socket and spigot dimensions and wall thickness are the same as AWWA standard Class D pipe. Approved by Underwriters' Laboratories.

Bends are provided with lugs to take socket clamps. Special coating of coal tar pitch varnish.

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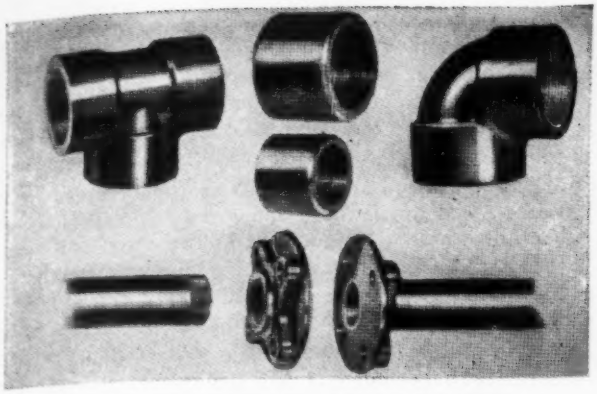
WHENEVER PIPING IS INVOLVED



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PROTECTION WHERE IT'S NEEDED!

For more than a quarter of a century Ace has guarded the health of millions of Americans by supplying fully corrosion resistant equipment to most of the nations successful water purification and waste water disposal installations. Our engineering staff backed by this invaluable experience and armed with the very best of material available is ready at your call to assist in answering your most difficult corrosion problems.

Shown here are just two items in the complete line of protection provided. Others are described in our 64 page illustrated catalog "Ace Rubber Protection" and in the Saran booklet sent free on request.

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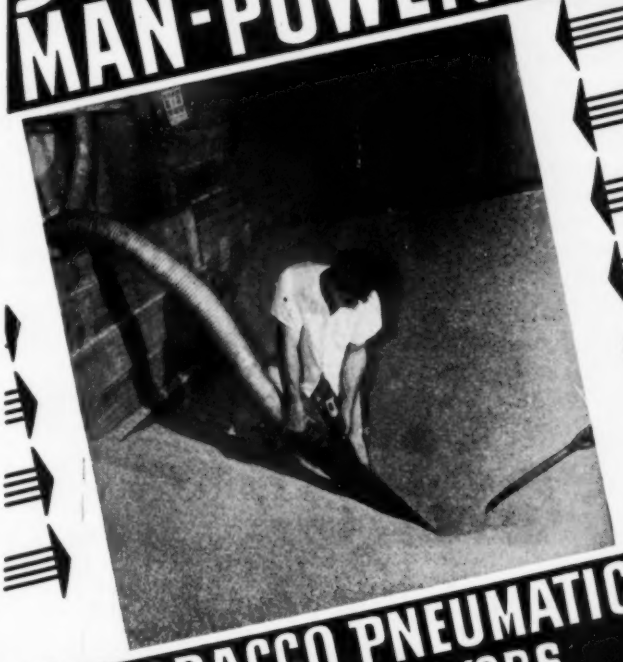
ACE HARD RUBBER LINED DIAPHRAGM VALVE

Save... MAN-POWER



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The following chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime, soda ash, bauxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

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MUNICIPAL WATER SOFTENING PLANT	Sandusky, Ohio
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LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
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BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
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MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
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CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
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room, preferably with tables and chairs, (2) Active participation in the actual functioning of the clubroom by a committee of the manufacturers, (3) Forehand knowledge by the members of the association that the clubroom is to take the place of room entertainment, and that means take the place of, (4) No substitution of the hotel bar for room entertainment during the technical sessions, (5) No peddling of refreshments by the hotel waiters, and (6) No expectation by registrants that manufacturers will also furnish room entertainment after the regular evening's entertainment is over.—O. K., Boys, I'll go quietly.

* * *

Who should turn up at the Elmira meeting of the N. Y. Sect. AWWA last month, but none other than Frank "Red" Griffiths of W & T's Texas district. Seems that "Red" is now "back home" and located in Syracuse. Welcome, Chum—You've come a "fur piece," as I learned to say when I lived in Texas.

Hazleton Type "M"

CHECK VALVE

with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

Flow switch insures pump against damage in event pump loses water during operation. Mercoid switch is actuated by valve-flap. Switch is connected into no-voltage coil of motor starter.

Write for Further Information.

BARRETT, HAENTJENS & CO.

HAZLETON PENNSYLVANIA

As a fellow who once aspired to be a lexicographer in the field of sanitary engineering, I'm happy to hear that the terminology in chlorination practice has at last been straightened out.

I understand that instead of the terms "marginal chlorination" and "breakpoint chlorination" or "superchlorination" the powers that be have decided that henceforth we shall say "combined residual chlorination" and "free residual chlorination." The former to be applied to any chlorination producing a "combined available chlorine residual," i.e., up to the breakpoint, and the latter term to be applied to chlorination producing "free available residual chlorine," i.e., after the breakpoint.

This means that the word "breakpoint" will henceforth be used as a noun to mean the point at which the residual chlorine drops and the type of residual changes from "combined" to "free." "Breakpoint" then will be the dosage in ppm. of chlorine at which this change occurs.—Now that terminology is "plumb sensible."

* * *

We are very happy to announce that *Water & Sewage Works* now has as a new subscriber, the best-known Water Commissioner in the U. S. A.—None other than Throckmorton P. (The Great) Gildersleeve of Summerfield. Welcome, Gildy! Hope to see you at an AWWA Convention some time.

* * *

Sooner or later I was bound to meet him.—I just had to meet him. —I had to see the fellow who lured Jo Quinn away from the Indiana State Board of Health and into the business of selling baking powder.—Well, I met him—him being the "Tony" Hulman. I met him in January at the Purdue Industrial Waste Conference and was I surprised. "Tony" turned out to be "one swell gent" to borrow an expression from the usually "quiet" Jo Quinn.

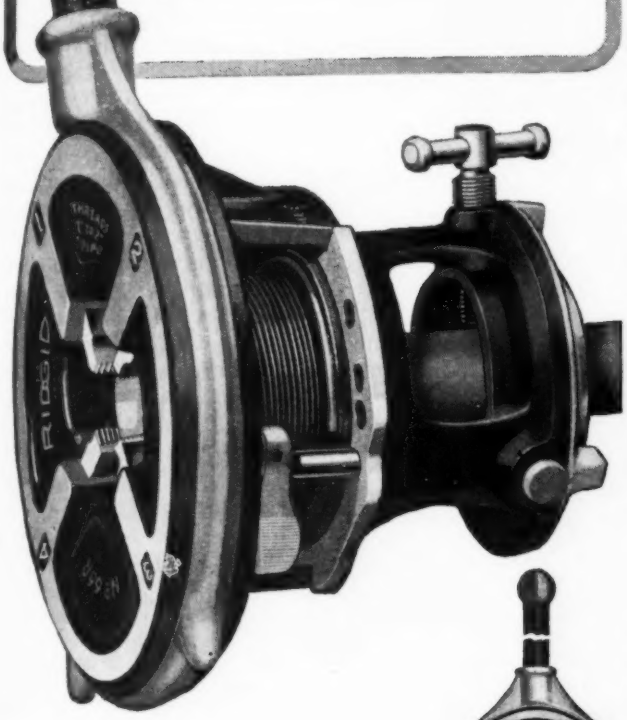
After I had pumped Jo for the whole story I learned that besides making "Clabber Girl Baking Powder" (plug) Tony had time to be chairman of the Indiana Water Resources and Flood Control Commission, and chairman of a Purdue Research Advisory Board, as well as run a gas company among several others. Not only that, but he, Tony, is also the motivating force in the Indianapolis Speedway, home of the 500 mile classic. What

You get perfect pipe threads more easily with this

Self-contained Semi-automatic

RIDGID

No. 65R Threader



It stands up handily on the floor.

● This modern threader is always ready to cut perfect threads on 1", 1¼", 1½" or 2" pipe. One set of chasers that stay in the die stock adjust to size in 10 seconds—workholder sets instantly, no bushings. Precision-made in all 23 of its rugged steel-and-malleable parts, it gives you micrometer perfect threads with least possible effort—and quickly. To cut smooth threads more easily—ask your Supply House for the efficient RIDGID No. 65R.

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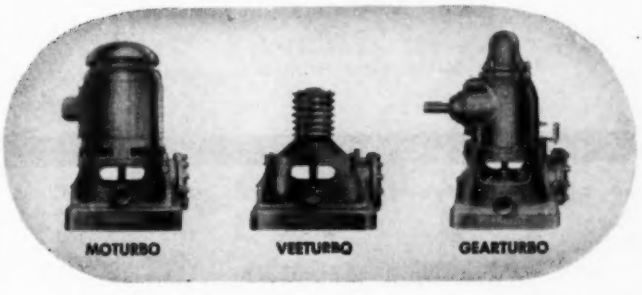
● Like thousands of others, you've probably put a new water pump at the top of your *must* list of improvements. *"Will I be able to get a Peerless?"* you ask. The answer is sounding more cheerful every day. *Yes, you will,* in the not too distant future. The big Peerless back-log of orders is being worked on 24 hours a day. The situation improves daily. But don't wait to place your order until your need becomes desperate. Consult with the nearest Peerless Distributor now and get your order on file. We'll do everything within our power to deliver your needed pump as soon as we can. Certain types can be delivered sooner than ther models—so check with Peerless now.



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Solid, Volute, and Split-Case Types
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Norwood engineers consider each project as a whole—from the time the initial sample of unprocessed water arrives at the laboratory until the finished insta'lation is turning out the proper volume of corrected water.

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The Best For Your Money
NORWOOD FILTERS
In The Long Run

a race! And what a guy to be running it.—P.S. Tony, I highly approve of Jo's move, now!

* * *

So help me, 'strue. We've heard of several sewage plants that have trouble with fish swimming into the final tanks from the lake or river, but so far as we know the Great Lakes Naval Training Station has the only sewage plant where a "No Swimming Allowed" sign hangs over the Final Tank. - - - For the benefit of the Navy Bootees (not the fish), who found it too inviting. Where *have* I heard that story before?

* * *

In our February issue we ran an article by "E. J. Ernie" Bear on Public Relations. Unfortunately, the footnote was left off the article, telling that Ernie had read that paper before the North Jersey Water Superintendents Association. Our apologies to both Ernie and the boys from North Jersey. *There* is a real live-wire organization if there ever was one.

THE SPILLWAY

[Overflow from the main section]

More Water & Sewage Works Projects

Recent Federal Loans for Construction Plans

Last August *Water Works and Sewerage* began the listing of water and sewage works projects for which the Federal government had made loans for the preparation of the plans. These funds which are made available through the Bureau of Community Facilities of the Federal Works Agency are to be repaid when construction is begun.

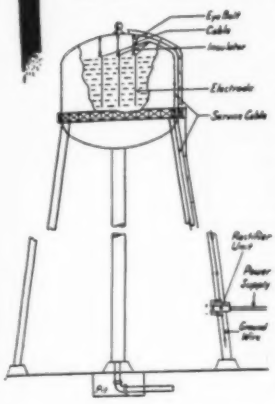
In August were listed 61 communities (77 projects) in 21 states; in September, 100 communities (122 projects) in 27 states, and in November, 165 communities (206 projects) in 35 states. Between Nov. 1, 1945, and March 15 of this year, the Bureau of Community Facilities has announced the issuance of loans for plan preparations to 526 communities (629 projects) in 46 states.

Communities receiving these most recent loans and the estimated cost of the completed projects are listed herewith by states.

Community and Facility	Estimated Cost
Alabama	
Andalusia (sewage)	$ 72,000
Andalusia (sewage)	36,000
Anniston (sewage)	438,000
Bay Minette (water)	208,000
Carrville (water)	37,400
Centre (sewage)	22,620
Centre (water)	12,830
Clanton (sewage)	54,000
Courtland (sewage)	50,000
Decatur (sewage)	44,350
Eden (water)	34,360
Foley (water)	70,800
Headland (water)	88,070
Jemison (water)	36,000
Lafayette (water)	43,500
Ragland (sewage)	42,000
Scottsboro (water)	192,500
Arizona	
Flagstaff (sewage)	86,150
Flagstaff (sewage)	71,050
Flagstaff (sewage)	30,000
Gilbert (sewage)	55,420
Safford (sewage)	76,100
Tempe (sewage)	70,000
Williams (water)	230,000
Arkansas	
Alexander City (sewage)	104,050
Arab (sewage)	108,120
Benton (sewage)	140,000
Benton (water)	112,000
Bessemer (sewage)	290,150
Black Oak (water)	33,150
Black Rock (water & sewage)	123,842
Brewton (water)	79,581
Brewton (sewage)	413,893
Caraway (water)	38,556
Caraway (sewage)	33,150
Clarksville (water)	313,302
Clarksville (sewage)	131,673
Clinton (water)	65,700
Clinton (sewage)	54,800

Stops Under-Water Rusting *INSTANTLY!*

The Electro Rust-Proofing System of Cathodic Protection instantly and permanently stops rust formation on the under-water interiors of steel tanks and other water storage or water handling equipment. It kills the cause of rust — without paint, chemicals or moving parts. It's a simple electrolytic process. We engineer it to meet your corrosion problem—exactly. We install and guarantee it. Unnecessary to drain tank. Initial cost is usually about the same as one good cleaning and painting job; operation cost is negligible. Electro Rust-Proofing is serving leading municipalities and industries now, in standpipes, flocculators, deep wells and other types of water handling equipment. Advocated by recognized independent authorities. Write for new fact-filled folder.



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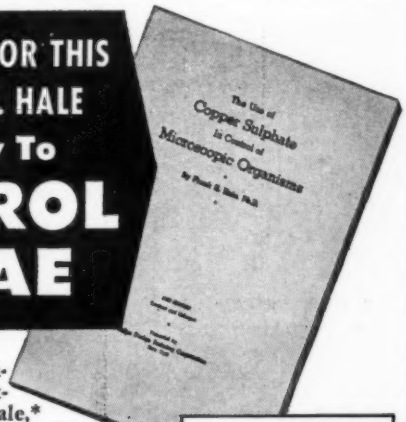
CONTROL ALGAE



This revised and enlarged edition, written by Dr. Frank E. Hale,* describes in detail methods of controlling various forms of microscopic life commonly dealt with in water supply systems. Descriptive material includes 48 clear photomicrograph studies of organisms discussed. Simplified methods of applying copper sulphate are also shown. ... Many of the most important water works specify Nichols *Triangle Brand* Copper Sulphate. Triangle Brand is available in several convenient sizes for water treatment. Write *today* for details and book.

*(Director of Laboratories, Dept. of Water Supply, City of New York

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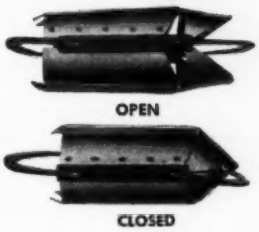

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Pulling forward opens the jaws that bite into obstructions. Reversing the pull on the bucket automatically closes jaws which hold load pulled back to street level. Write for complete details.

CHAMPION CORPORATION 4718 SHEFFIELD HAMMOND, IND.

Community and Facility	Estimated Cost
Cotter (sewage)	76,550
Crawfordsville (sewage)	38,550
Decatur (water)	5,625
Decatur (sewage)	33,150
Fayetteville (sewage)	115,449
Flippin (water)	42,000
Fordyce (sewage)	78,000
Fort Smith (sewage)	449,267
Green Forest (water)	28,260
Green Forest (sewage)	39,985
Hazen (water and sewage)	83,304
Helena (water)	38,400
Helena (sewage)	49,900
Helena (sewage)	32,350
Joiner (water)	38,750
Joiner (sewage)	33,150
Lake City (sewage)	44,100
Luxoria (sewage)	55,600
Leslie (water)	54,800
Leslie (sewage)	43,900
McCrory (sewage)	66,800
Magnolia (sewage)	211,490
Manila (water)	23,535
Marion (sewage)	196,083
Marshall (sewage)	60,250
Melbourne (water)	48,440
Monette (sewage)	55,600
Mountain Home (water)	70,000
Mount Ida (sewage)	73,039
Murfreesboro (sewage)	76,950
Nettleton (water)	82,150
Nettleton (sewage)	54,900
Oneonta (water)	125,000
Oneonta (sewage)	112,618
Parkin (water)	82,350
Rector (water)	45,335
Rector (sewage)	40,630
Salem (water)	50,000
Town of Manila (sewage)	55,600
Town of Mulberry (sewage)	45,000
Tuckerman (sewage)	51,914
Turrell (sewage)	44,400
Watson (water)	39,090
Waverly (water)	36,290
Wynne (sewage)	98,600
Yellville (water)	79,010
California	
Berkeley (sewage)	175,000
Burbank (sewage)	73,100
Burbank (sewage)	38,000
Burbank (water)	23,885
Corning (sewage)	117,700
Dixon (sewage)	89,600
East Bay Mun. Dist. (sewage)	9,192,810
Groveland Sew. Dist. (sewage)	9,900
Los Gatos (sewage)	186,000
Los Gatos (sewage)	120,000
Los Gatos (sewage)	83,000
Rialto (sewage)	61,000
Richmond (sewage)	1,026,500
Santa Ana (sewage)	654,670
Tuolumne (sewage)	92,200
Connecticut	
Derby (sewage)	176,400
Middletown (sewage)	179,400
Norwich (sewage)	1,204,500
Stratford (sewage)	1,005,800
Westport (sewage)	1,092,683
Delaware	
Dagsboro (water)	78,445
Rehoboth (water)	178,400
Florida	
Chipley (sewage)	152,157
Cocoa (water)	260,000
Dania (water)	160,605
Hollywood (sewage)	481,603
Jacksonville Beach (water)	102,000
Plant City (water)	42,350
Sanford (sewage)	220,000
Stuart (sewage)	244,500
Wauchula (water)	65,000
Georgia	
Adel (water)	17,800
Cairo (sewage)	136,330
Claxton (water)	43,000
College Park (water)	49,535
College Park (sewage)	102,857
Dublin (sewage)	29,890
Gordon (water)	34,438
Hogansville (water)	47,552
Homerville (sewage)	53,877
Lakeland (sewage)	60,000
Madison (water)	109,000
Metter (water)	36,500
Pelham (sewage)	53,000
Statesboro (water)	39,510
Statesboro (sewage)	99,385
Saint Mary's (water)	79,619
Statham (sewage)	25,000
Thomson (water)	122,250
Valdosta (water)	595,000
Vienna (water)	80,000
Warrenton (sewage)	55,500
Idaho	
Hailey (sewage)	140,000
Mountain Home (sewage)	31,000
Pocatello (sewage)	375,000
Salmon (water)	147,000
Illinois	
Antioch (sewage)	36,500
Aledo (sewage)	86,600
Beckmeyer (sewage)	101,000
Belleville (sewage)	426,000
Belleville (sewage)	214,263
Benton (sewage)	34,450
Bloomington (sewage)	1,000,000
Bunker Hill (sewage)	137,250
Camp Point (sewage)	96,000
Camp Point (water)	92,595
Carlinville (sewage)	132,500
Coulterville (sewage)	75,372
Cicero (sewage)	1,300,000
De Soto (water)	94,000
Dietrich (sewage)	49,200
Dietrich (water)	43,800
Effingham (sewage)	350,000
Elmwood Park (water)	219,157
Fairbury (water)	21,700
Fairbury (sewage)	111,000
Fairbury (sewage)	21,800
Farina (water)	81,000
Flat Rock (sewage)	48,795
Galva (water)	140,000
Geneseo (water)	110,000
Green Valley (water)	800,000
Homewood (water)	71,000
La Harpe (water)	68,700
Lenzbury (water)	59,000
Lexington (water)	61,100
Martinsville (sewage)	82,857
Milford (water)	68,000
Milford (sewage)	125,000
Mounds (sewage)	55,500
Nokomis (sewage)	80,000
Oblong (sewage)	45,284
Pana (sewage)	178,480
Pocahontas (water)	71,000
Percy (sewage)	67,000
Peoria (sewage)	1,267,140
Peoria Heights (sewage)	77,541
Pittsfield (sewage)	90,000
Ridgeway (sewage)	84,000
Roanoke (water)	30,388
Rockton (water)	48,000
St. Clair Co. (sewage)	902,000
St. Clair Co. (sewage)	800,000
Silvis (water)	163,000
South Pekin (sewage)	103,500
Sterling (sewage)	66,000
Summit (water)	232,730
Toledo (sewage)	69,450
Tilden (water)	116,200
Vandalia (sewage)	208,600
Westmont (water)	20,800
Willisville (sewage)	52,600
Wood River (sewage)	774,900

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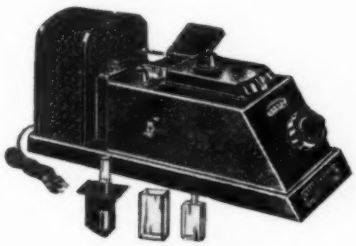

Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined.

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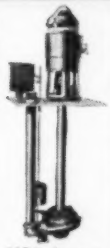

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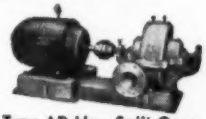

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NAME .....

STREET .....

CITY .....

Community and Facility	Estimated Cost
Indiana	
Bristol (water)	63,985
Bristol (sewage)	72,300
Crown Point (sewage)	164,500
Decatur (sewage)	430,000
East Chicago (sewage)	1,465,240
Elkhart (sewage)	3,000,000
Gary (sewage)	760,155
Marion (sewage)	370,300
Meridian Hills (sewage)	208,500
New Carlisle (sewage)	87,168
Noblesville (sewage)	264,000
Plymouth (sewage)	280,000
Thorton (sewage)	90,250
Union City (sewage)	71,000
Wakarusa (sewage)	21,500
Iowa	
Brayton (water)	21,000
Carlisle (sewage)	97,729
Casey (sewage)	97,652
Dallas Center (water)	10,000
Grimes (water)	20,300
Jesup (sewage)	111,300
Lamoni (water)	44,700
Lamoni (water)	83,500
Lamoni (sewage)	55,500
Lamoni (sewage)	28,500
Moulton (water)	20,000
Richland (sewage)	52,500
Kansas	
Alta Vista (water)	43,140
Alta Vista (sewage)	57,800
Fort Scott (sewage)	219,400
Goodland (sewage)	19,800
Holyrood (sewage)	66,100
Junction City (sewage)	337,300
Junction City (sewage)	167,000
Kansas City (sewage)	475,200
Leavenworth (sewage)	200,606
Lenexa (sewage)	72,978
Leonardville (sewage)	46,000
Little River (sewage)	77,500
Miltonvale (sewage)	88,000
Spring Hill (water)	66,263
Walnut (water & sewage)	91,800
Winona (sewage)	45,000
Kentucky	
Dawson (sewage)	65,967
Earlington (sewage)	169,659
Franklin (sewage)	76,389
Georgetown (sewage)	80,896
Glasgow (sewage)	165,000
Glasgow (sewage)	68,000
Henderson (sewage)	41,717
Jefferson Co. (sewage)	1,472,700
Leitchfield (sewage)	107,700
Louisville (sewage)	4,997,000
Madisonville (water)	663,012
Pleasureville (water)	72,992
Russell Spring (sewage)	75,309
Russellville (water)	25,000
Russellville (sewage)	122,000
Versailles (water)	38,000
Versailles (sewage)	29,000
Louisiana	
Bossier City (water)	40,000
Bossier City (sewage)	123,000
Boyce (sewage)	38,539
Breaux Bridge (water)	74,000
Bunkie (sewage)	131,217
Chaney (sewage)	18,278
Columbia (sewage)	12,396
Duson (water)	32,000
Gueydan (sewage)	169,000
Gueydan (sewage)	8,591
Hammond (water)	90,258
Hammond (sewage)	137,704
Jonesboro (water)	57,387
Kentwood (water)	106,000
Kentwood (water)	7,865
Lafayette (water)	210,000
Lafayette (sewage)	515,000
Lafayette (sewage)	475,000
Logansport (sewage)	60,000
Madisonville (sewage)	82,867
Mansfield (water)	79,435
Napoleonville (sewage)	72,220
Napoleonville (sewage)	27,958
Ponchatoula (sewage)	25,366
Springfield (water)	15,925
St. Francisville (sewage)	50,000
St. Martinsville (water)	34,000
St. Joseph (sewage)	74,630
Winnfield (water)	50,581
Maine	
Lubec (sewage)	58,600
Maryland	
Chesterton (water)	62,000
Crisfield (water)	242,000
Crisfield (sewage)	300,000
Massachusetts	
Agawam (sewage)	126,716
Chicopee (sewage)	350,980
Fall River (sewage)	898,000
Grafton (water)	232,000
Grafton (sewage)	177,000
Hatfield (water)	72,511
Monson (sewage)	125,581
Town of Essex (water)	269,000
Town of Norfolk (water)	105,000
South Dighton (water)	210,000
Upton (water)	124,000
Michigan	
East Jordan (sewage)	99,160
Montague (sewage)	78,000
Muskegon (sewage)	554,329
Minnesota	
Aitken (sewage)	164,250
Chisago City (sewage)	72,190
East Grand Forks (sewage)	290,300
Farmington (sewage)	60,950
Hastings (sewage)	208,025
Lindstrom (sewage)	116,152
Rochester (sewage)	1,540,500
Rosemount (sewage)	75,144
St. Paul Park (sewage)	77,489
Verndale (water)	55,000
Verndale (sewage)	95,000
Warren (sewage)	44,187
Young America (water)	45,000
Mississippi	
Calhoun City (water)	60,000
Corinth (sewage)	127,400
East Tupelo (sewage)	29,000
Gulfport (sewage)	1,000,000
Leaksville (water)	52,750
Lexington (sewage)	99,169
Lexington (sewage)	84,427
Lucedale (sewage)	120,000
Marks (water)	62,781
Marks (water)	37,140
Meadville (sewage)	40,500
Mize (water)	22,100
Monticello (water)	11,500
Monticello (sewage)	82,000
Mount Olive (sewage)	46,000
New Hebron (water)	34,876
Pontotoc (water)	64,500
Pontotoc (sewage)	150,000
Quitman (sewage)	53,070
Sandersville (water)	30,000
Summit (sewage)	81,308
Missouri	
Alma (water)	35,000
Alton (water)	60,000
Benton (water)	35,050
Braymer (water)	85,073
Chaffee (water & sewage)	88,500
Clarksville (sewage)	60,470
Clinton (sewage)	276,328
Dexter (water & sewage)	141,000
Gideon (water)	68,000
Kennett (water & sewage)	155,000
Kennett (sewage)	86,604
Knobnoster (sewage)	67,400

That's a lot of capacity—an all-welded-panel gas holder more than 1,000 feet high!

So far, we've never found a customer who needed a single holder that big—but we've built them as large as 10,000,000 cubic feet and as small as 100 cubic feet.

However, 60,000,000 cubic feet *is* the total capacity of all these Stacey Brothers all-welded holder installations—an enviable record when you consider this type of construction is comparatively new.

There are good reasons for this overwhelming customer endorsement; Stacey Brothers pioneered the all-welded type of construction. Measuring capacity with "know-how", this 60,000,000 cubic feet of construction represents a wealth of experience—experience that pays off in speedier erection and trouble-free operation.

But there are other important advantages, too—inherent design features. The famous patented Stacey Brothers All-Welded-Panel construction not only licks the problem of internal corrosion behind vertical legs and between laps, but results in a structure that's mechanically round and free of unsightly deformations.

When you need gas-holder capacity, it will pay you to get a quotation and recommendations from Stacey Brothers. No obligation, of course. May we hear from you?

Stacey Brothers TANKS

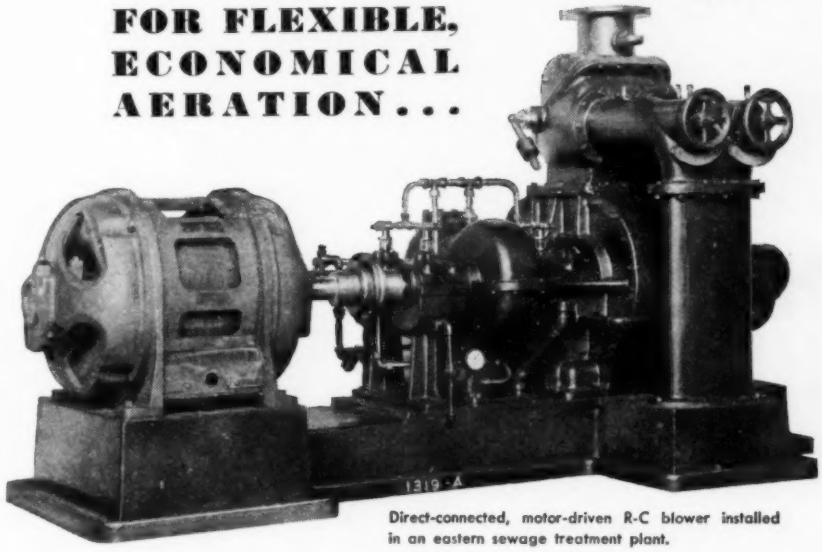
STACEY BROTHERS GAS CONSTRUCTION CO.
One of the Dresser Industries
5535 VINE STREET • CINCINNATI 16, OHIO

Linn (sewage)	68,900
Marionsville (sewage)	69,026
Marionsville (sewage)	57,260
Marshfield (water)	56,900
Marshfield (sewage)	63,900
Nevada (sewage)	392,930
Palmyra (sewage)	52,140
Parma (sewage)	76,200
Pattonsburgh (sewage)	79,000
Perry (sewage)	64,000
Sikeston (sewage)	435,000
Slater (sewage)	176,319
St. Peters (sewage)	28,100
Summersville (water)	30,000
Union star (water)	54,677
Wellston Dist. (sewage)	41,000
Montana	
Chester (sewage)	83,012
Deer Lodge (water)	91,460
Deer Lodge (water)	78,700
Plentywood (water)	71,000
Plentywood (sewage)	42,487
Nebraska	
Cambridge (sewage)	114,980
McCook (sewage)	123,681
North Platte (sewage)	350,000
Nevada	
Battle Mountain (sewage)	54,000
Reno (water)	415,000
New Hampshire	
Keene (water)	83,000
Keene (sewage)	66,130
New Jersey	
Buena Vista (water)	116,110
Buena Vista (sewage)	160,000
Camden (sewage)	1,424,403
Clifton (sewage)	568,000
Clifton (sewage)	185,000
Hammonton (sewage)	91,800
Passaic (sewage)	208,860
Paterson (sewage)	959,000
Town Livingston (sewage)	335,000
New Mexico	
Belen (sewage)	100,000
Farmington (water)	120,000
Farmington (sewage)	58,320
Raton (sewage)	83,200
North Carolina	
Chapel Hill (sewage)	316,000
East Spencer (water & sewage)	90,000
Lexington (water)	215,000
Lexington (water)	136,000
Lexington (water)	62,500
Newton (water)	250,000
Newton (sewage)	81,000
Norwood (water)	107,555
Norwood (sewage)	94,575
Salisbury (water)	414,023
Salisbury (sewage)	71,185
Town of Franklin (water)	33,200
Town of Franklin (sewage)	12,900
Town of Morgantown (water)	172,100
Town of Morgantown (sewage)	268,500
Warsaw (water)	45,000
Warsaw (water)	15,000
Warsaw (sewage)	35,000
North Dakota	
Devil's Lake (sewage)	157,400
Maddock (water)	105,800
Maddock (water)	7,700
Maddock (sewage)	77,300
Sheyenne (water)	59,000
Sheyenne (sewage)	55,000
Ohio	
Akron (sewage)	5,118,000
Athens (sewage)	375,000
Bellevue (sewage)	410,500
Brookville (water)	46,000
Butler (sewage)	60,950
Cambridge (sewage)	191,250
Clyde (sewage)	120,000
De Graff (sewage)	149,000
East Liverpool (sewage)	330,989
East Liverpool (sewage)	633,000
Fostoria (sewage)	536,000
Fremont (sewage)	465,000
Franklin County (sewage)	1,500,000
Ironton (sewage)	265,500
Lucas (sewage)	56,500
Milford (sewage)	227,840
Pleasant Hill (water)	10,300
Portsmouth (sewage)	62,743
Portsmouth (sewage)	33,315
Portsmouth (sewage)	17,520
Portsmouth (sewage)	12,867
Richmond Heights (water)	150,500
Sidney (sewage)	267,000
St. Marys (sewage)	393,950
Oklahoma	
Atoka (water)	137,676
Barnsdall (sewage)	71,064
Barnsdall (sewage)	66,212
Choteau (water)	60,000
Elk City (water)	131,190
Elk City (sewage)	141,820
Enid (water)	646,910
Enid (water)	279,515
Enid (sewage)	650,000
Goodwell (sewage)	15,925
Guthrie (water)	113,000
Guthrie (sewage)	345,655
Henryetta (water)	101,973
Hugo (water)	107,250
Oklahoma City (sewage)	2,774,000
Paden (water)	49,773

USE R-C

dual-ability

FOR FLEXIBLE, ECONOMICAL AERATION...



Direct-connected, motor-driven R-C blower installed in an eastern sewage treatment plant.

ROTARY POSITIVE

The R-C Multi-Capacity Blower employs the long-proved Rotary Positive Displacement principle developed by us almost a century ago. Two simple impellers deliver a definitely predetermined volume.

CENTRIFUGAL

Where applications can best be served by Centrifugal Blowers, Roots-Connersville offers single or multi-stage units in a wide range of designs and capacities to meet your exact requirements.

● In one compact Roots-Connersville blower, you can have three different capacities to meet varying conditions.

The chamber of this Multi-Capacity unit is built in two sections of different widths, each with its own impellers, driven by one motor. Two by-pass valves permit delivery of air into the line from either section, or both. The unused section passes the air without compression, and thus with practically full power saving.

R-C Multi-Capacity units provide flexibility with economy in first cost, power and space.

This is an example of *dual-ability* which is built into every Roots-Connersville product. This combination of sound engineering, plus long-time economical operation accounts for the wide acceptance of our equipment.

Send for bulletin 23-B-12 for helpful data on blowers, gas meters and filter vacuum pumps for sewage treatment and waterworks. Our engineers are at your service without obligation.

ROOTS-CONNERSVILLE BLOWER CORP.

One of the Dresser Industries

604 Mount Avenue, Connersville, Indiana

Roots CONNERSVILLE SINCE 1854

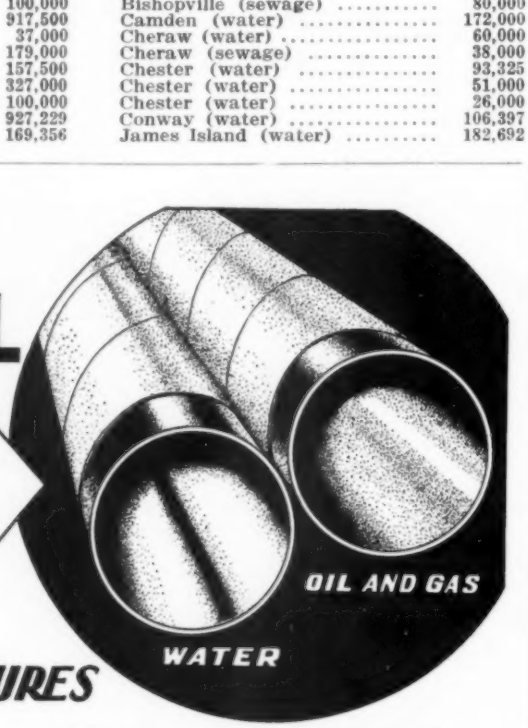
MULTI-CAPACITY BLOWERS

ROTARY POSITIVE AND CENTRIFUGAL BLOWERS • EXHAUSTERS • BOOSTERS
LIQUID AND VACUUM PUMPS • METERS • INERT GAS GENERATORS

Community and Facility	Estimated Cost
Oregon	
Milwaukie (sewage)	163,379
Oregon City (sewage)	216,000
Pennsylvania	
Ambridge (sewage)	448,861
Blakely (sewage)	845,715
Borough Evansburg (sewage)	24,500
Borough Green Tree (sewage)	262,500
Borough South Heights (sewage)	36,500
Bradford (sewage)	548,500
Cambria Co. (water)	100,605
Crescent Township (water)	143,800
Du Bois (sewage)	347,000
Freedom (sewage)	100,000
Greenburg (sewage)	917,500
Harrisburgh (sewage)	37,000
Hopewell Township (sewage)	179,000
Mount Union (sewage)	157,500
New Brighton (sewage)	327,000
Northampton (sewage)	100,000
Pittsburgh (sewage)	927,229
Pittsburgh (sewage)	169,356
Pittsburgh (sewage)	167,400
Pittsburgh (sewage)	146,000
Rochester (sewage)	275,000
South Williamsport (sewage)	225,000
Van Port (water)	58,000
Rhode Island	
Cranston (sewage)	1,000,000
Jamestown (sewage)	119,267
Narragansett (water)	24,500
Providence (water)	1,300,350
South Carolina	
Batesburg (sewage)	91,230
Bennettsville (water)	30,750
Bennettsville (sewage)	29,500
Bishopville (water)	38,500
Bishopville (sewage)	80,000
Camden (water)	172,000
Cheraw (water)	60,000
Cheraw (sewage)	38,000
Chester (water)	93,325
Chester (water)	51,000
Chester (water)	26,000
Conway (water)	106,397
James Island (water)	182,692
Liberty (water)	87,770
Monchs Corner (sewage)	90,282
Mullins (sewage)	67,500
Myrtle Beach (sewage)	167,920
North (water)	19,700
North (sewage)	11,000
Orangeburg (sewage)	385,292
Port Royal (water)	38,500
Prosperity (sewage)	50,071
Ridge Spring (sewage)	56,500
Scranton (water)	28,000
Spartanburg (water)	482,500
Sullivans Island (sewage)	190,000
Timmonsville (water)	16,100
Timmonsville (sewage)	91,500
Timmonsville (sewage)	36,500
Winnsboro (water)	132,000
South Dakota	
Faith (water)	55,000
Hill City (water)	48,000
Irene (sewage)	49,000
Midland (sewage)	22,600
Newell (water)	32,400
Wall (sewage)	32,900
Texas	
Alamo Heights (sewage)	10,938
Alta Loma (water & sewage)	128,000
Amarillo (sewage)	1,088,500
Athens (water)	42,325
Athens (sewage)	27,550
Ballinger (water)	398,000
Benjamin (water)	75,950
Brenham (sewage)	60,000
Center (sewage)	22,800
Commerce (water)	102,425
Commerce (water)	22,905
Commerce (water)	19,900
Crosbyton (water)	22,000
Crosbyton (sewage)	25,000
Friona (sewage)	54,600
Fort Worth (water)	143,500
Fort Worth (water)	210,000
Galen Park (water & sewage)	60,071
Galveston Co. (water & sewage)	210,000
Littlefield (water)	29,250
Littlefield (sewage)	69,000
Mesquite (water)	36,000
Odessa (water)	1,007,000
Odessa (sewage)	256,463
Raymondville (water)	180,240
Raymondville (sewage)	86,280
Rocksprings (water)	39,463
Seadust (sewage)	53,800
Seymour (water)	73,500
Seymour (sewage)	166,000
Seymour (sewage)	82,000
Sweeny (water & sewage)	189,515
Texas City (water)	265,500
Waco (sewage)	335,250
Whitesight (water)	20,500
Tennessee	
Elizabethton (water)	200,000
Jackson (water)	482,200
Jackson (sewage)	160,550
Lafayetteville (water)	114,612
Murfreesboro (sewage)	122,100
Rutledge (water-sewage)	50,000
Town Fayettville (water)	190,000
White Pine (water)	45,000
Utah	
Centerville (sewage)	77,000
Lindon (water)	20,720
Kaysville (sewage)	32,000
Nephi (water)	16,150
Nephi (water)	8,550
Roosevelt (water)	185,000
Salt Lake City (sewage)	1,050,000
Spanish Fork (sewage)	75,000
South Salt Lake (water)	196,700
Town Clearfield (water)	30,200
Town Perry (water)	55,000
Town Pleasant View (water)	69,000
Virginia	
Arlington Co. (sewage)	1,576,000
Cambria (water)	96,047
Cambria (sewage)	117,500
Gate City (water-sewage)	125,000
Gordonsville (sewage)	99,125
Portsmouth (water)	330,000
Portsmouth (water)	132,000
Portsmouth (sewage)	713,000
Richmond (water)	1,000,000
Town Fairfax (sewage)	182,550
Washington	
Bellingham (sewage)	160,445
Bellingham (sewage)	95,835
Bryn Mawr (sewage)	159,855
Enumclaw (sewage)	141,000
McCleary (sewage)	79,750
Morton (water)	47,600
Morton (sewage)	14,565
Rainier Vista (sewage)	314,250
Sedio-Wooley (sewage)	204,900
Vancouver (sewage)	711,000
Westport (water)	77,000
West Virginia	
Bridgeport (water)	46,975
Charleston (sewage)	1,436,940
Davis (water)	22,700
South Charleston (sewage)	500,000
Thomas (sewage)	32,337
Wierton Heights (sewage)	145,000
Wisconsin	
Barron (sewage)	69,550
Brokaw (sewage)	31,500
Cobb (water-sewage)	60,220
Dodgeville (sewage	312,000

HILL – HUBBELL

machine applied
STEEL PIPE
PROTECTION



V HAS THESE IMPORTANT FEATURES

- V POSITIVE BOND
- V 2 COATS UNDER FELT
- V CONTROLLED PROCESSING
- V UNIFORM APPLICATION

Mechanically cleaned and primed steel pipe with conditioning of primer indoor controlled, guarantees positive bond. The enamel is applied over the primer in two separate applications to eliminate air bubbles and holidays. Uniform specified thickness of primer and enamel thermostatically controlled at point of application over properly heated pipe at correct temperatures.

MOST MODERN PIPE PROTECTION PLANT

GENERAL PAINT CORPORATION
HILL, HUBBELL & CO. • Division • Cleveland, Ohio
• EXPORT OFFICE: SAN FRANCISCO, CALIFORNIA, U. S. A. •

Dresser (sewage)	73,732
Green Bay (sewage)	346,290
Hortonville (water-sewage)	155,500
Ladysmith (sewage)	368,021
Livingston (water)	50,000
Mellen (sewage)	53,700
Mellen (sewage)	43,300
Pardeeville (sewage)	102,257
Poynette (sewage)	66,570
Town of Jacobs (water)	8,650
Trempleau Co. (sewage)	68,000
Trempleau Co. (sewage)	50,000
Wrightstown (water)	64,520
Wrightstown (sewage)	65,508
Wyoming	
Greybull (water)	46,000
Laramie (sewage)	87,000
Newcastle (sewage)	75,000
Town of Greybull (sewage)	85,470
Territory of Hawaii	
County (water)	52,000
County (water)	28,400
County (water)	261,000
Kauai Co. (water)	50,000
Maui Co. (water)	220,700

MANUFACTURERS' and EQUIPMENT NEWS

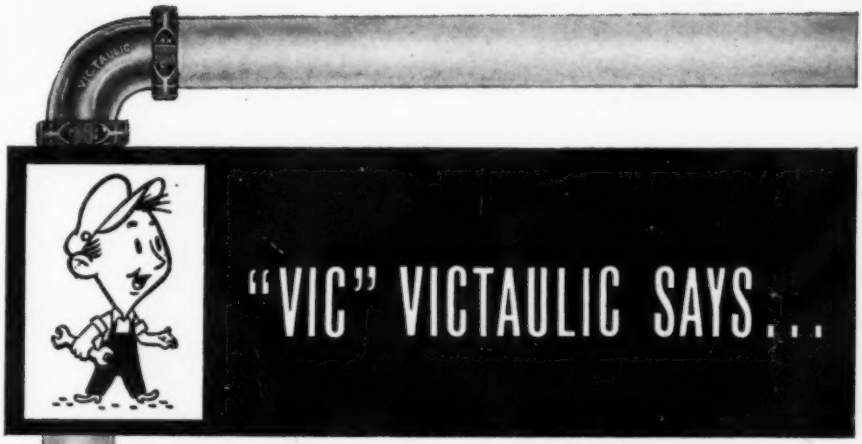
Electro Rust-Proofing Corporation Expands

Wallace & Tiernan Co., Inc., has recently purchased a half interest in the Electro Rust-Proofing Corp. of Dayton, Ohio. Thereby W & T has joined The Dorr Co. as sole owners of Electro Rust-Proofing, with a 50% participation by these two leading companies in the water and sewage field.

E. H. Ingle

Mr. E. H. Ingle, pioneering owner, will continue as president and general manager of the company, whose present organization is being retained in whole. Under the new ownership of W & T and Dorr, plans are being completed for pronounced expansion of research and follow through service in cathodic methods of corrosion control.

The Electro Rust-Proofing Corp. specializes in the furnishing of equipment and engineering services for the cathodic protection of tanks and submerged metal structures in water and sewage works. The company is entering its 10th year and has several thousand installations through the U. S. and Canada.



"VIC" VICTAULIC SAYS...

"Pipe fitting ain't what it used to be... No sir!"

"There's no need today for bulling pipe with heavy tongs and other back-breaking, time-consuming operations. You can "button up" your lines with Victaulic Couplings.

"They're simplicity itself . . . and fast. A socket wrench is the only tool. Only two bolts to make up . . . and they're always accessible.

"Victaulic makes fittings too . . . elbows, tees, etc. . . . of every type. They're handy, believe me. Swivel and set 'em at any angle . . . no bolt holes to line up.

"Best of all, Victaulic systems are tight. If you're not convinced, ask a Victaulic user in any field of industry.

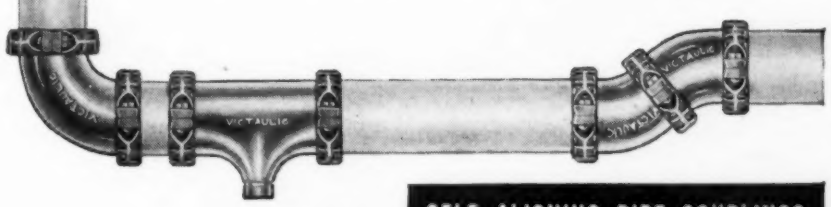
"Believe me, we *know* Victaulic Couplings and Full-Flow Fittings can help you. Find out how... now!"

Write for new Victaulic Catalog and Engineering Manual

VICTAULIC COMPANY OF AMERICA

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

Victaulic, Inc., 727 W. 7th St., Los Angeles 14, Calif.
Victaulic Company of Canada, Ltd., 200 Bay St., Toronto
For export outside U. S. and Canada: PIPECO Couplings and Fittings: Pipe Couplings, Inc., 30 Rockefeller Plaza, New York 20, N. Y.



Have you considered Victaulic for your piping requirements?

Sizes—¾" through 60"

SELF-ALIGNING PIPE COUPLINGS

VICTAULIC

EFFICIENT FULL-FLOW FITTINGS

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Thousands of Cities

HAVE LAYNE WELL WATER SYSTEMS

Quality that gives supreme satisfaction was the ultimate deciding factor with thousands of cities that now own Layne Well Water Systems. These cities—and they range from the Nation's largest to those of only a few inhabitants—were careful to place known performance before idle claims. In buying Layne Well Water Systems they obtained the very best that skill and experience could create.

Layne Well Water Systems have long been first choice by big and little cities everywhere—first choice for highest efficiency, lowest cost operation and unparalleled long life. In a like manner, thousands of industries;—processing plants, factories, railroads, oil refineries, ice plants and irrigation projects also buy and use Layne Well Water Systems.

Each Layne Well Water System is built to fulfill a specific need—and built to produce the utmost amount of water under any and all conditions. For illustrated literature, address Layne & Bowler, Inc., General Offices, Memphis 8, Tenn.

HIGHEST EFFICIENCY

Layne Vertical Turbine pumps are available in sizes to produce from 40 to 16,000 gallons of water per minute. High efficiency saves hundreds of dollars on power cost per year.

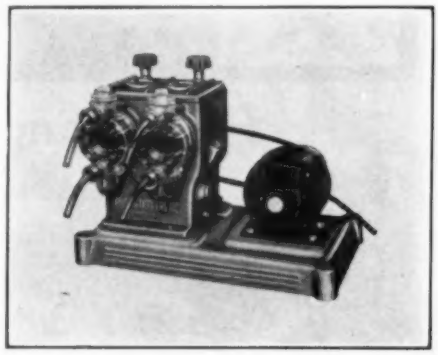
AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Texas Co., Houston, Texas ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Western Co. of Minnesota, Minneapolis, Minn. ★ International Water Supply Ltd., London, Ontario, Canada ★ Layne-Hispano Americana, S. A., Mexico, D. F.

LAYNE

WELL WATER SYSTEMS
VERTICAL TURBINE PUMPS

Duplex Deluxe Chem-O-Feeder

Just released for civilian use by Proportioneers, Inc., is their Duplex Deluxe Chem-O-Feeder, a new chemical diaphragm type proportioning pump which delivers chemical reagents in an almost continuous stream. This new feeder is designed for positive injection of one or two chemicals at predetermined



adjustable rates, and may be adapted for many uses, particularly in the feeding of chemicals for water treatment. Feeding rate of each chemical may be adjusted by changing the stroke rate through a two step cone pulley with fine adjustment of the rate being made by a stroke length adjustment knob on top of the Chem-O-Feeder. Transparent plastic reagent heads make operating parts visible.

Complete information on this new unit may be obtained from Proportioneers, Inc., 9 Codding St., Providence, R. I.

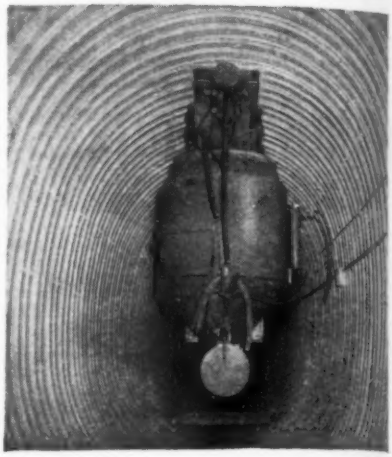
Bituplastic

The Wailes Dove - Hermiston Corp., of Westfield, N. J., has announced a new type of cold applied coating material called Bituplastic. This material should be of particular interest in sewage work construction and maintenance as it can be applied to damp surfaces.

Bituplastic contains no solvents, and because it is an irreversible emulsion, can be applied to damp surfaces after which it drys shortly, becomes waterproof and does not revert back to its original state. Bituplastic can be applied as very thick films in individual coats, and produces a film thickness heavier than can be secured from ordinary thin paints. It will not flow or sag at temperatures up to the point of disintegration, which is about 600 deg. F., and it is practically incombustible.

The company recommends this new cold applied coating material

what designed strength can mean to your tunnel liner jobs



Rear view of weighing hopper. This elliptical batching tunnel of No. 10 gage Armco Steel is 11 by 13 feet and 460 feet long. Raw aggregates were stored over a 10-foot tunnel, 260 feet long, and wet sand over an 8-foot tunnel, 190 feet long.

This is how three aggregate tunnels built of ARMCO Corrugated Liner Plates helped speed construction of the Norfork Dam—a 1,500,000 cubic yard job.

First, the plates were easy to handle and install. Then, their designed strength permitted placing the tunnel directly beneath the aggregate pile, which attained a height of 60 feet. Delays caused by freezing in cold weather were avoided because the aggregate was handled from the bottom.

Armco's method of bolted construction made it a simple matter to locate the hoppers at any desired point. When the job was done the ARMCO Liner Plates were removed, nested together and stored in a minimum of space for future use.

There is a type and gage of Armco Plates to meet every tunnel condition. You can order exactly what you need for the job and the chances are you'll be "holing through" ahead of schedule. Write today for information on your specific needs. Armco Drainage & Metal Products, Inc., and Associated Companies, 1365 Curtis St., Middletown, O.

ARMCO

ARMCO

Tunnel Liner Plates

as an ideal protection to sunlight and weather, moisture, temperature changes, gasoline, oil and grease, and will protect metal, concrete, masonry, stone, asbestos cement products, and insulating material.

For further information write to the Wailes Dove-Hermiston Corp., Westfield, N. J.

R. F. Orth Advanced at Johns-Manville

Johns-Manville Corp. has announced that R. F. Orth has been appointed Staff Manager of the Transite Pipe Section of the company. Mr. Orth joined Johns-Manville in 1924, after graduation from

Texas A & M in 1923. In 1940 Mr. Orth was named Staff Manager for Transite Pipe sales in the west, and in 1941 came to New York as Manager of the Public Utility and Electrical Dept. He now succeeds Chas. A. McGinnis, resigned, as Staff Manager of J-M's expanding Transite Pipe Section.

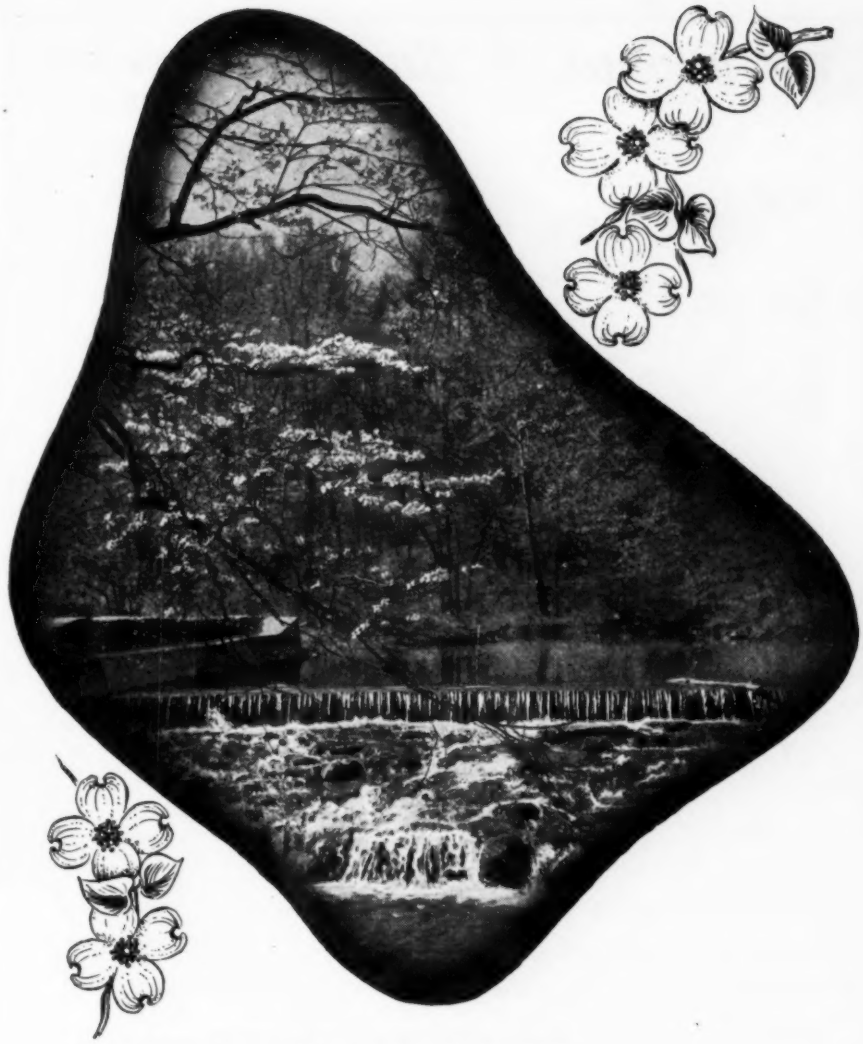
Rockwell Meter Division Sponsors Contests

$2,000.00 In Cash to Be Given Winners

The Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., has announced two simultaneous contests designed to stimulate public thinking about the community benefits resulting from a program of metering all water services. A total of $2,000.00 in cash will be awarded with a first prize of $500.00 in each contest.

In Contest No. 1 the entrant is to write the last line to a "jingle" about 100 per cent metering. Contest No. 2 is to be of the essay type in which the contestant is to write a paper of 2,000 words or less on the subject "How a Community Is Benefited by Metering All Services."

Complete details, rules, regulations, and entry coupons for both contests are appearing in the trade



SEE THE DIFFERENCE,
IN COLOR-REMOVAL TOO

This spring would you like to obtain better color-removal? Then investigate the effect of activated silica sol as a coagulant aid.

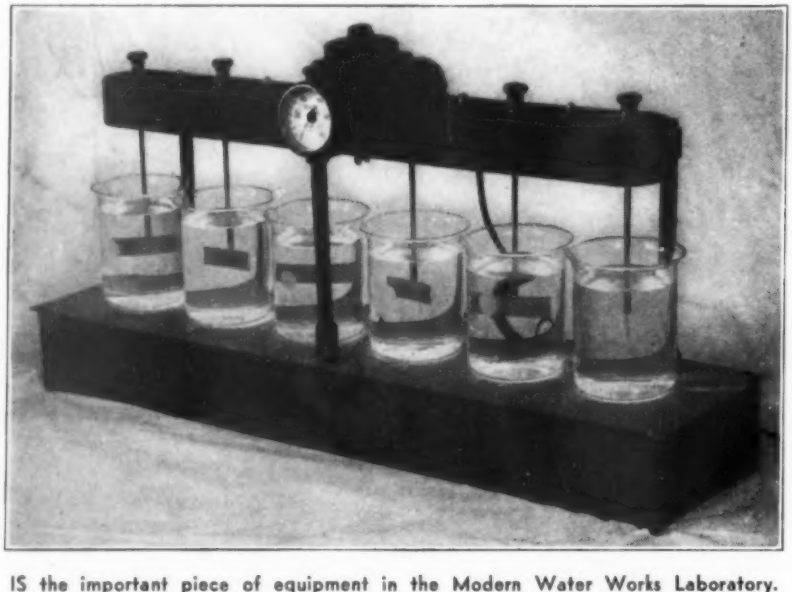
N-Sol Processes of water coagulation are chosen because they shorten settling time, increase the capacity of filters, reduce the chemical costs, and also, improve the quality of the water produced . . . clear, sparkling water even when colors as high as 300 are encountered. In one water treatment plant, the color-removal was 85% to 90% before the use of the N-Sol Process, and after adoption the color-removal was stepped up to 95%.

Instead of a light, weak color floc, get a heavier, tougher floc and hence better color-removal with the N-Sol Process. Samples of N-Sol Process activated silica sols for jar tests are available on request.

N-SOL PROCESSES FOR WATER COAGULATION

DEVELOPED AND PATENTED BY
PHILADELPHIA QUARTZ COMPANY, PHILADELPHIA 6
AVAILABLE UNDER LICENSE WITHOUT CHARGE

THE *Phipps & Bird* LABORATORY MIXER...



IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of chemical dosages with this mixer. Write for literature.

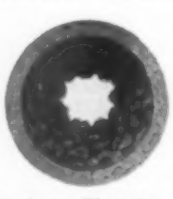
PHIPPS & BIRD, INC.
RICHMOND, VA.
"SOUTHERN CENTER FOR LABORATORY APPARATUS AND CHEMICALS"

★ THE NATIONAL METHOD • OVER 35 YEARS EXPERIENCE ★

SAVE *For* VICTORY

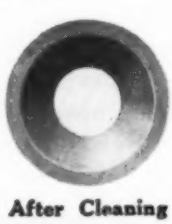
★ ★ ★

EVERYWHERE Americans are being asked to "SAVE FOR VICTORY." Water works superintendents, engineers and public officials can do more in this connection by investigating the National Method of water main cleaning. This method restores the carrying capacity of pipe to at least 95 per cent of that of new mains, thereby eliminating the necessity for purchase of new mains. Aside from this the National Method makes possible lower pumping costs, greater delivery, reduced insurance rates and clean water.



Before Cleaning

The NATIONAL METHOD



After Cleaning

GUARANTEED TO RESTORE 95% ORIGINAL CAPACITY

The National Water Main Cleaning Co.
50 Church St. Branches: New York 7

115 Peterboro St., Boston 15, Mass.
P. O. Box 749, Mayaguez, Puerto Rico
7103 Dale Ave., St. Louis 17, Mo.
3707 Madison St., Kansas City 2, Mo.
3812 Castellar St., Omaha 5, Neb.
P. O. Box 683, Jacksonville 1, Fla.
205 West Wacker Dr., Chicago 6, Ill.
501 Howard St., San Francisco, Calif.
2028 Union Ave., Montreal, Can.
576 Wall St., Winnipeg, Can.

press and the Company's house organ—The Pittsburgh Empire Water Journal.

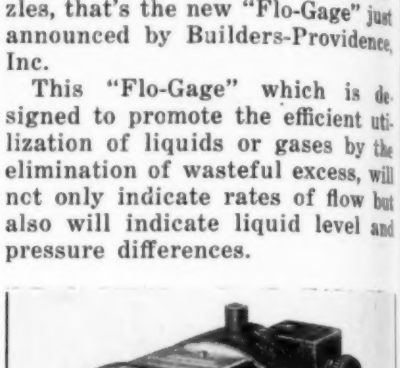
The contests close on August 31, 1946. The names of the winners will be posted in Pittsburgh-Empire Meter exhibit booths at the fall Water Works Conventions.

Note: Complete details appear on ad, page 3, in this issue.

Builders-Providence New "Flo-Gage"

A midget differential meter to indicate the rate of flow of liquids and gases through lines containing orifice Venturi tubes and insert nozzles, that's the new "Flo-Gage" just announced by Builders-Providence, Inc.

This "Flo-Gage" which is designed to promote the efficient utilization of liquids or gases by the elimination of wasteful excess, will not only indicate rates of flow but also will indicate liquid level and pressure differences.



The "Flo-Gage" may be used to measure water used in backwashing filters and softeners, cooling water, fuel gas or oil, or dry or liquid chemicals being fed to a main flow by chemical feeders.

Features of the new Builders' Flo-Gage include accuracy, legibility, sensitivity, little space, and a minimum of maintenance. The gage can be furnished to measure gpm., ft. per min., cu. ft. per hr., etc.

For further information write the Builders-Providence Co., Inc., 10 Codding St., Providence, R. I. Ask for Bulletin No. 360.

National Water Main Cleaning Co. Expands and Moves Offices

Frank Made Chief Engr. and Field Mgr.

The National Water Main Cleaning Co. has recently moved to larger offices at 50 Church St., New York City. According to Clinton Inglee, president, the company has expanded its services throughout the

western hemisphere and therefore needs larger quarters.

J. A. Frank has been promoted to chief engineer and field manager and will spend the major part of his time traveling for the company.

C. F. Hauck Heads New Dept. at Hall Laboratories

Announcement has been received of the establishment of a special department to handle problems of industrial waste and stream pollution by the Hall Laboratories, Inc., of Pittsburgh. Heading up the new department will be Charles F. Hauck, until recently an engineer at Ravenna Ordnance Center.

C. F. Hauck

For five years prior to his service at the Ordnance Center, Mr. Hauck was senior chemist and assistant to the superintendent of the Southerly Sewage Treatment Plant at Cleveland.

The new department will undertake the development of methods for treating industrial wastes economically, extension of the regular engineering service of the Hall Laboratories to include water and waste leaving industrial plants, as well as to study plant operation to reduce the volume of waste.

Demand-Type Oxygen Mask

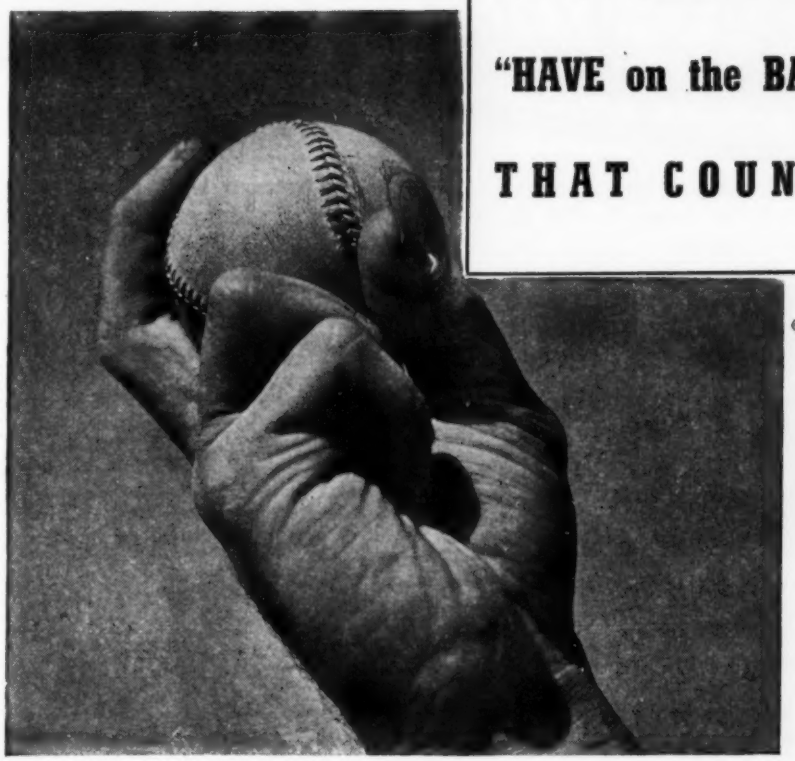
Mine Safety Appliances Co., of Pittsburgh, Pa., has developed a new demand-type oxygen mask for respiratory protection in unbreathable atmospheres. The mask is a cylinder type oxygen breathing apparatus which features simplicity and ease of operation.

One type of mask has the oxygen cylinder on the wearer's back and supplies oxygen for an hour; another has a smaller cylinder with a front sling. Further information may be obtained from the Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh 8, Pa.

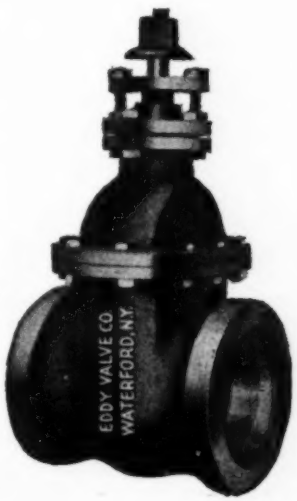
Changes at Pitometer Co.

Several changes in the Pitometer Co., New York City, have been made recently. Edward S. Cole, who developed the Pitometer 50 years ago,

IT'S WHAT YOU "HAVE on the BALL" THAT COUNTS



—AND IT'S PARTICULARLY TRUE IN MAKING VALVES



Valves look pretty much alike. Valves, practically all of them, will give you pretty good service. Our job, as we see it, is to make an *exceptionally good* valve. We've been doing that for years, as hundreds of water works men know.

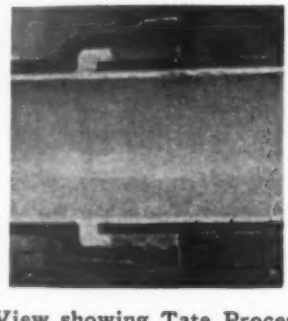
We make a complete line of valves for water works service, almost all of which are readily available where and when you need them. Specify EDDY—and get a better valve.

EDDY FOR LONGER SERVICE

EDDY
VALVE COMPANY
WATERFORD, NEW YORK

The TATE Cement Lining Process
Restores efficiency of old Water Mains

Now is the time to investigate the Tate Cement Lining process —and see what it can do to restore the efficiency of your old water mains.



View showing Tate Process in Pipe Joint. Note thoroughness of Lining.

Write for Literature.

What the TATE Process accomplishes

1. Water mains cleaned and cement-lined without removing pipe.
2. Eliminates discoloration and further cleaning costs.
3. Reduces pumping costs.
4. Restores reduction in head and flow co-efficients. This means full fire protection and lowered insurance rates.
5. All joints cement-lined . . . just one continuous pipe.
6. Does the job without interruption of service to consumer.

TATE PIPE LININGS, Inc.
ANDOVER, MASS.

84" pipe—Spring Lake, N. J.

FLANGED PIPE

FLEXIBLE JOINT PIPE

BELL & SPIGOT PIPE

SPECIAL CASTINGS

SHORT BODY BELL & SPIGOT SPECIALS

Large stock enables us to make prompt shipments.

CAST IRON PIPE

SIZES 2" TO 84"

Warren Foundry & Pipe Corp.

11 Broadway, New York

Warren Pipe Company of Mass., Inc.

has resigned as president, but will continue his connection with the company as consulting engineer. Mr. Cole has held the position of president of the Pitometer Co. since 1915.

Egbert D. Case, who has been with the company since 1914, and was formerly vice president and general manager, has been elected the new president.

E. Shaw Cole has been elected vice president and chief engineer with headquarters in New York, and Cyrus R. Bird, with offices in Chicago, has been named vice president and western manager.

Wilson Heads Worthington-Gamon

Charles E. Wilson, vice president of Worthington Pump and Machinery Corp., Harrison, N. J., has

been appointed president of the Worthington-Gamon Meter Co., Newark, a subsidiary of the parent company.

Taylor Offers Fluoride Color Comparator

W. A. Taylor Co. of Baltimore, Md., is offering a fluoride color comparator for determining the fluoride content in water. Color standards range from 0.0 to 1.6 ppm. in increments of 0.2 ppm.

G. W. Knight Heads Penn Salt Washington Office

G. Webber Knight has been appointed Manager of the Washington, D. C. office of the Pennsylvania Salt Manufacturing Co., according to an announcement received from the company recently. Mr. Knight will look after all company interests in the nation's capital and will act as a clearing house in all Penn Salt matters involving both domestic and foreign government agencies.

A. G. Brown Heads Vertical Pump Manufacturers

At the recent meeting of the National Association of Vertical Turbine Pump Manufacturers in Chicago, Arnold G. Brown, manager of the Pump Div. of Fairbanks, Morse & Co., Chicago, was elected president. Mr. Joe Downs of A. D. Cook, Inc., Lawrenceburg, Ind., was elected vice president.

Tatman Chairman, Avery President Roots-Connersville

At a recent meeting of the directors of Roots-Connersville Blower Corp., one of the Dresser Industries, Mr. J. S. Tatman was elected chairman of the Board and John Avery was elected President and General Manager of Roots-Connersville. Mr. Tatman has been with

John Avery J. S. Tatman

Roots-Connersville since his graduation from Purdue University in 1902. He is a vice president of the Compressor Air & Gas Institute. Mr. Avery is a graduate of the U. S. Naval Academy and has been associated with General Electric Co. and was manager of the Blower and Compressor Dept. of Allis-Chalmers Mfg. Co., before coming to Roots-Connersville as president.

Patterson Returns to Hill, Hubbell

Hill, Hubbell & Co., Division of General Paint Corporation, Cleveland, Ohio, has announced the return of Bryan Patterson to their staff as Pipe Line Corrosion Engineer. Patterson returns after a four-year wartime leave of absence.

Shortly after the war began, Patterson was loaned by Hill-Hubbell to the U. S. Engineers for special wartime expediting and emergency service. During the four years of

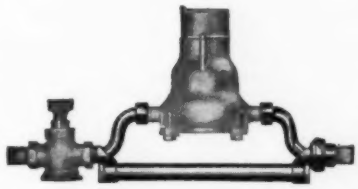
Modern
METER MOUNTINGS
FOR ALL TYPES OF METER
SETTINGS *in any Climate*

New!

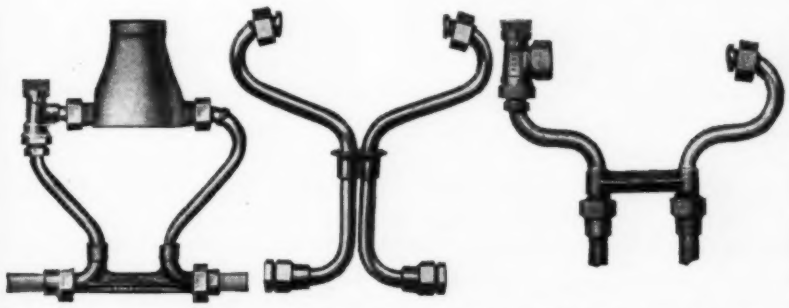
Here is a COPPERSETTER which raises the meter only 2½" above the service line level.

It makes available to the shallowest service all the important advantages of COPPERSETTERS mentioned below.

Excellent for basements also!



Shown here is the plain type but the valve type is also available.



The 70 series is made in heights for raising the meter from 6" to 36" above the service line.

The 90 series provides a flexibility in the spacing of connections to the service line.

The 80 series is installed on vertical riser pipes of copper or iron and is made in plain or valve types.

FORD COPPERSETTERS

These proven and perfected meter mountings provide many advantages in line with the modern trend in water service engineering. They are easily installed but last almost forever. All-copper water passages and easy bends insure hydraulic efficiency. Meter changes do not disturb the physical connection of the service, insuring trouble-free meter maintenance. COPPERSETTERS are made with and without valves and in a variety of types, sizes and connections which permits perfect tailoring to any job.

Ask for information about COPPERSETTERS—no obligation!

The
FORD METER BOX COMPANY, INC.,
WABASH, INDIANA

For

DAMS, TUNNELS, SEWERS

Specify

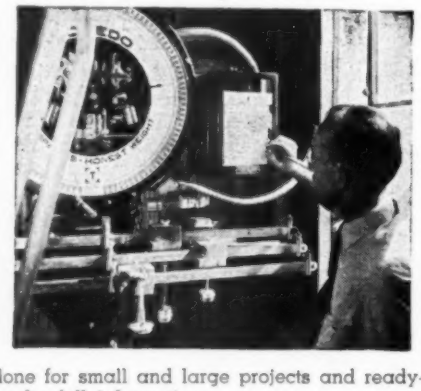
[SC]² PRECISION CONCRETE CONTROL

[SC]² **Control provides fast, accurate concrete batching which controls the variables to close tolerances. It includes:**

Moisture Determination. Test made in one minute. A test for every batch when necessary.

Moisture Compensation. for moisture content of aggregates. Compensation is instantaneous and automatic. No calculations, tables or charts necessary.

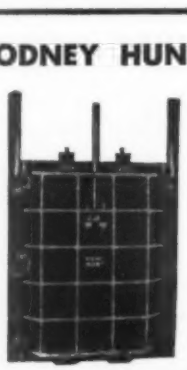
Graphic Record. showing the delivered weight of each ingredient in every batch. Reveals all weighing errors, and insures delivery of specified quantities. Valuable aid to inspectors. Reduces inspection cost.



Let us show you what [SC]² CONTROL has done for small and large projects and ready-mix plants. Write today for full information.

SCIENTIFIC CONCRETE SERVICE CORPORATION
724 Salem Avenue, Elizabeth 3, N. J.

RODNEY HUNT



GATES and HOISTS

Metal or timber sluice gates of all sizes and designs, approved by engineers everywhere. Improved gate stands and hoists for hand or motor operation. Also flap and mud valves, shear and filler gates, trash racks and rakes. Dependable canal equipment from dam to tail-race since 1840.

Write for Special Catalog Today!

RODNEY HUNT

RODNEY HUNT MACHINE CO.
118 Lake St., Orange, Mass., U. S. A.

FOR BETTER

pH Control and WATER TESTS

there is nothing like

NON-FADING GLASS COLOR STANDARDS

Pocket Comparator No. 605

Permanent reliability of Hellige Glass Color Standards, accuracy of color comparison, simplicity of the technique, and compactness of the apparatus are exclusive features of Hellige Comparators not found in any similar outfits.

WRITE FOR BULLETIN No. 602

HELLIGE

INCORPORATED
3718 NORTHERN BLVD., LONG ISLAND CITY 1, N.Y.
HEADQUARTERS FOR COLORIMETRIC APPARATUS

wartime developments, Patterson carried out some highly interesting emergency engineering work. "Pat" as he is known to gas and oil, and construction engineers, looks forward with much enthusiasm to the expansion of Hill-Hubbell facilities for pipe corrosion production. Mr. Patterson will have charge of all Hill-Hubbell engineering services in the Western states.

A. J. Olson Link-Belt's K-C Manager

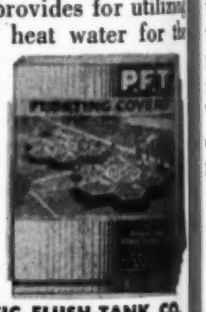
Arthur J. Olson, formerly district sales engineer for Link-Belt at Chicago, has been appointed district sales manager at Kansas City, Mo., to succeed Max Giffey, who resigned after 40 years' service with the company. Mr. Olson has been with the Link-Belt Co. since 1918. For the past 20 years he has specialized on equipment for the meat packing and allied industries.

With Mr. Olson in the Kansas City office will be J. Arthur Townsend and Leroy C. Rathsam, district sales engineers.

Over 225 P. F. T. Floating Covers in War Service

The health of our fighting men and war workers is being safeguarded by modern sewage disposal plants. We are doing our part by delivering on time P.F.T. Floating Covers and other sewage treatment equipment.

The P.F.T. Floating Cover for single and stage digestion hastens the digestion process, and provides for utilizing the sewage gas to heat water for the digester tank.



Catalog No. 232 contains complete information, including specifications. Write for your copy.

P.F.T. **PACIFIC FLUSH-TANK CO.**
4241 Ravenswood Ave., Chicago, Ill.
New York Charlotte, N.

Simpson Completes 45 Years with Mueller

J. W. "Bill" Simpson, Vice Pres. in charge of Sales for the Mueller Co., Decatur, Ill., was recently honored at a special event in recognition of his 45 years' service to the company. "Bill" Simpson, who is widely known throughout the water,

gas and plumbing trade, began his service to the Mueller Co. in 1899 as a messenger boy barely out of school. During his 45 years with the company, Mueller Co. has expanded from one small plant in Decatur to six large plants, including branches in Chattanooga, Los Angeles, and Sarnia, Ontario.

New Micromet Feeder

Calgon, Inc., of Pittsburgh has announced the development of a new feeder for Micromet to be used in home water supply lines. Micromet is not a water softener, but is a vitreous phosphate with slow dissolving action which eliminates red water troubles, corrosion, and

scaling in domestic hot water systems. To protect the water system, the feeder is placed on the water inlet to the home and completely filled with two pounds of Micromet This installation will require a recharge of one-half pound of Micromet a month.

Solvay Opens Southwestern Branch

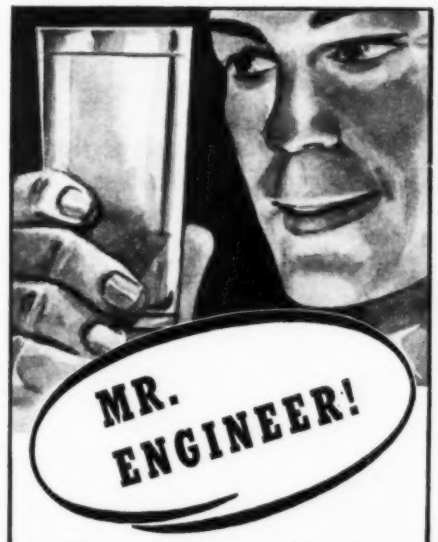
Solvay Sales Corp., has established a new office in Houston, Tex., to serve the states of Texas, New Mexico and Arizona. Col. S. O. Taylor will be in charge, having returned recently from three years service as Executive Officer at Patterson Field, Dayton, O. Prior to the war Col. Taylor was in the St. Louis branch of the company for a number of years.

Philadelphia Quartz Appointments

The Philadelphia Quartz Co. has announced the advancement of John C. Russell to the position of Sales Manager. Mr. Russell has been associated with the company since 1924, and has been Assistant Sales Manager since 1942. Mr. Russell is also Secretary and Director of an associate company, the American Doucil Co., manufacturers of synthetic zeolites.

Carl F. Wolcott has been named Manager of Foreign Sales and is also Employment Manager of the company.

Other appointments include Russell J. Emmons, Industrial Relations Manager and John H. Wills, Assistant Patent Manager.

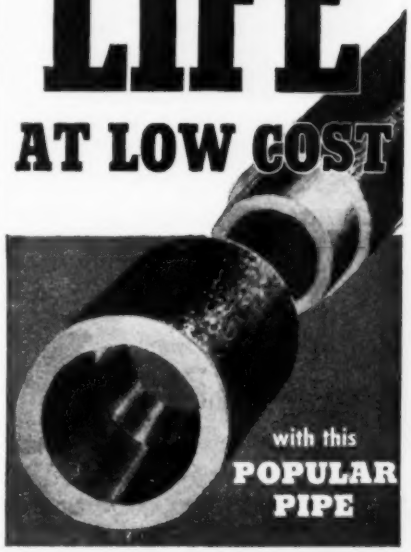


What are your customers saying about CHLORINE TASTE?

Virginia's "ESOTOO" will eliminate it. Write for complete information.

VIRGINIA SMELTING COMPANY
WEST NORFOLK, VIRGINIA

LONG LIFE AT LOW COST



Hundreds of progressive communities are using ORANGEBURG PIPE because it assures long, trouble-free service, is easy to handle and install, does not corrode or tuberculate, is connected with TAPERWELD Joints which require no joining compound, and offers many other superior features. This modern non-metallic, non-rigid pipe is widely and successfully used for

- House-to-Sewer Connections
- Conductor and Irrigation Lines
- Industrial Drainage
- Septic Tank Filter Beds (Perforated)
- Foundation Drains (Perforated)

Write for bulletins giving physical and chemical characteristics and other interesting data. THE FIBRE CONDUIT COMPANY, DEPT. WWS-10-45, ORANGEBURG, N. Y.

ORANGEBURG
The Root-Proof Pipe

CONTACT

LAKESIDE ENGINEERING CORPORATION

Chicago 6 **Illinois**

222 West Adams St.

FOR

WATER SOFTENING by the Zeolite or Lime-soda methods.

WATER FILTERING to remove Suspended solids, color, odor or taste.

SEWAGE TREATMENT by the Aero-filter which offers all of the advantages of other types of trickling filters plus better momentary distribution.

Spiraflo Clarifier for improved clarification, including scum and oil removal.

WRITE FOR INFORMATION

VOGT BROTHERS TRAFFIC MODEL FIRE HYDRANT

A.W.W.A.

VOGT BROTHERS MFG. CO. Incorporated LOUISVILLE, KY.

MAIN AT 14th

VOGT

VOGT MFG. CO., Incorporated LOUISVILLE, KY.

P. O. BOX 1122

AERO-MIX

AERATOR—MIXER

A Size and Type to Fit Your Problem in Water or Sewage Treatment.

WRITE FOR INFORMATION

G. D. Lain Research Engineer Am. Iron and Steel Institute

George D. Lain has been appointed research engineer of the Committee on Steel Pipe Research of the American Iron and Steel Institute. The Committee carries on industry-wide research and development of the use of steel pipe.

Mr. Lain, a graduate of Carnegie Institute of Technology, was recently production manager of the Consolidated Machine Tool Co., Rochester, N. Y., and has had broad experience in the pipe field. He served as industrial and research engineer with the A. M. Byers Co. of Pittsburgh from 1916 to 1925.

From 1925 to 1938 he was with the Reading Iron Co. in various technical and operating positions, and became general superintendent of tube works. Mr. Lain's experience also has included production, maintenance and executive positions with other steel producers.

Metcalf at Pittsburgh-Des Moines Dies

Walter H. Metcalf, contracting engineer for Pittsburgh-Des Moines Steel Co., died suddenly on February 19. Mr. Metcalf, whose home was in Des Moines, was well known throughout Iowa and the middle west for his work in the water works field and as a veteran of 24 years of service with the company, for whom he had contracted many large all-steel water tanks and towers. Mr. Metcalf had been with the company since his graduation from Iowa State College in 1922.

Barber Represents Hooker in N. Y. and Penna.

Neil M. Barber has been assigned to the Hooker Electrochemical Co. sales staff to cover the territory comprising upper N. Y. State and Northern Pennsylvania. His headquarters will be at Niagara Falls. A graduate of Dartmouth University, Mr. Barber has spent a number of years in the Niagara Falls plant of the company and more recently was engaged in sales development work.

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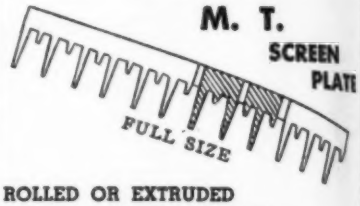

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LITERATURE AND CATALOGS

Proportioning Pumps

Just off the presses, is Bulletin No. 242, on **Chemical Treatment of Water with Wilson Pulsafeeder Proportioning Pumps,** issued by the manufacturer, the Lapp Process Equipment Div. of the Lapp Insulator Co., Inc., Leroy, N. Y. Besides pictures of the different types and models of the Wilson Pulsafeeder, the bulletin contains information on the application of these chemical feeders to water sterilization, swimming pool treatment, boiler water treatment, threshold treatment, sewage treatment, and water coagulation.

A diagram shows the inner workings of the feeder with a description of the several advantages to be obtained by this design. These include especially built check valves, hydraulically-balanced diaphragm valves, oil relief valves, vacuum relief valves, micrometer stroke control, and double-cam eccentric gears. Two pages of the bulletin are devoted to diagrams of installations of typical applications. These include pumped water supply, gravity water supply, swimming pool water, and sewage treatment. This new Bulletin No. 242 may be obtained from the Lapp Process Equipment Div., Lapp Insulator Co., Inc., Leroy, N. Y.

Lubricated Plug Valves

Just issued by the Walworth Co., a four page folder **No. 4-F, Rev. 2** explains and illustrates **Walworth Lubricated Plug Valves,** Class 125, with pressure Sealed Lubrication. These Class 125 lubricated plug valves were designed to meet the demand for an inexpensive valve incorporating the principal features of the regular pattern lubricated plug valve. The flanged patterns have the same face to face dimensions as standard wedge or double disc gate valves. The folder shows several different designs and style of valve. Also included in the folder is a list of recommended service lubricants for the Walworth lubricated plug valves. This folder No. 4-F Rev. 2, on these valves may be obtained from Walworth Co., 60 East 42nd Street, New York 17, N. Y.

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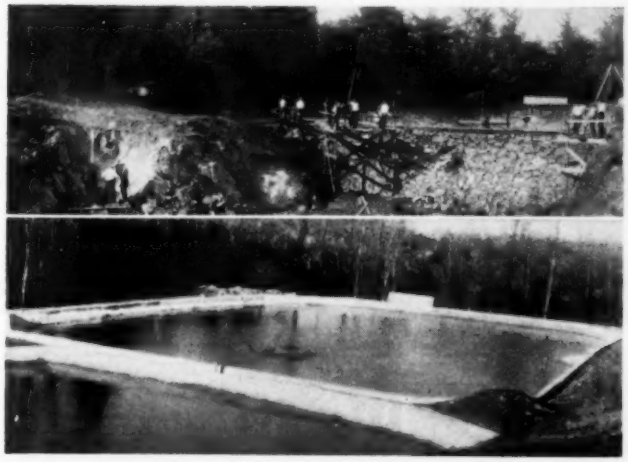

RESERVOIR REBUILT WITH "GUNITE"

Shown above are "before" and "after" pictures of a twin reservoir at Saranac Lake, New York, which we lined with reinforced "GUNITE" in 1928. The original reservoir was partially lined with rip-rap, leaked considerably, and was very difficult to clean. The "GUNITE" lining converted this structure into a modern sanitary reservoir, with no leakage, which can be cleaned quickly and easily.

Our 72 page bulletin C2300 describes many reservoir jobs and other types of "GUNITE" work. Write for your free copy.

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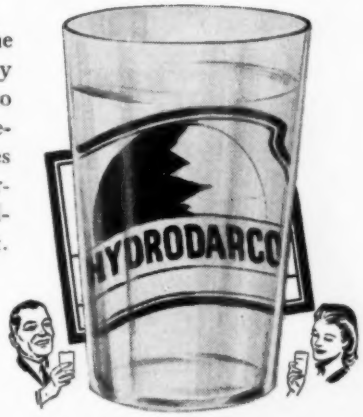

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Unusual Water Tanks

New water tanks of unusual design that are serving Warsaw, and Winona Lake, Ind., are exciting unusual interest to passersby, according to the story in the January 1946 **Water Tower** issued by the Chicago Bridge & Iron Co. These adjoining municipalities are served by the Northern Indiana Public Service Co., which has installed

these new type conispherical structures supported on sloping cylindrical columns that come together at the top and are welded to the tank bottom. One of the tanks is shown in an accompanying illustration. This larger tank of 250,000 gal. capacity is installed on the Warsaw water distribution system and is 40 ft. in diameter with 31½ ft. water depth. The four supporting columns are 4½ ft. in diameter and the central riser is 4 ft. in diameter. There are no outside ladders on the structures. Access to the balcony, roof and inside of the tanks is provided by means of rungs installed inside one of the sloping columns and a vertical cylinder or access tube extending from the top of this column, through the water in the tank, to the roof manhole. This is a desirable feature as the sloping columns are easier to climb than a ladder on a vertical or almost vertical column. The **Water Tower** is issued by the Chicago Bridge & Iron Co., under the editorship of Milo E. Smith, and is published at 2421 McCormick Bldg., Chicago 4, Ill.

Testing Plugs

"Stop!! Stop What? Any Size and Kind of Pipe. How? Easily and Quickly with the Original Climax High Pressure Testing Plugs. Formerly made by the C. M. Kemp Mfg. Co., Baltimore, now exclusively manufactured by the Richmond Foundry & Manufacturing Co. of Richmond

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Oskaloosa, Iowa

Va." Thus reads the first page of a four-page folder on the subject of Climax testing plugs. These high pressure plugs for bell or spigot ends of cast iron pipe or steel pipe are made for the purpose of plugging pipe lines that are to be tested. The company also makes a gas main plug and a low pressure plug, the latter in 7, 8, 9, 10 and 12 inch sizes.

If you are planning on laying and testing any pipe line, we suggest you write to the Richmond Foundry & Manufacturing Co. for this folder on testing plugs.

Gardner-Denver Products

When we were a young man operating a filter plant, little did we know that the governor XX on the Corliss steam engine which ran our pumps was the result of an invention of R. W. Gardner who founded the company later to become known as the Gardner-Denver Co.

The story of this company, its origin, and its present organization, products, markets, etc., is interestingly told in a well illustrated brochure issued by the company, entitled *Gardner-Denver Since 1859*. While only a small part of the brochure is devoted to pumps, the entire booklet is of interest to any person furnishing water to the oil industry, the mining industry, or the railroad industry, as well as many manufacturing processes.

The brochure may be obtained from the Gardner - Denver Co., Quincy, Ill.

Sludge Pumps

One of the things that add to the readibility of catalogs or bulletins is a well organized photographic essay on some phase of production problem about which the catalog is concerned. A good example of this is the production story of the Carter sludge pump, as given in Bulletin No. 4502, **Plunger Sludge Pumps,** issued by the Ralph B. Carter Co., of Hackensack. From the first welding arc struck on the pump chassis to the careful overall prime coat on the finished job, pictures with notes follow the production of a Carter sludge pump in its travels through the Carter factory. This particular bulletin also contains detailed specifications of the standard type and "Balto" type sludge pump, as well as a diagram showing exclusive Carter sludge pump features.

Bulletin No. 4502 may be had by writing Ralph B. Carter Co., Hackensack, N. J.

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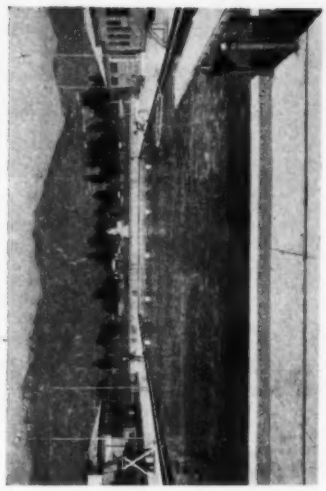

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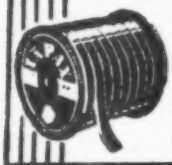

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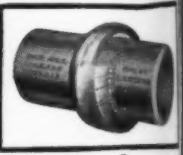

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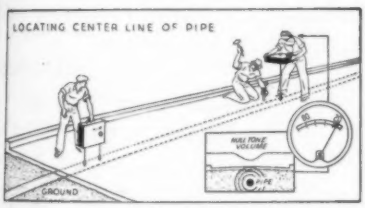

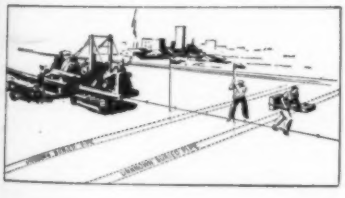

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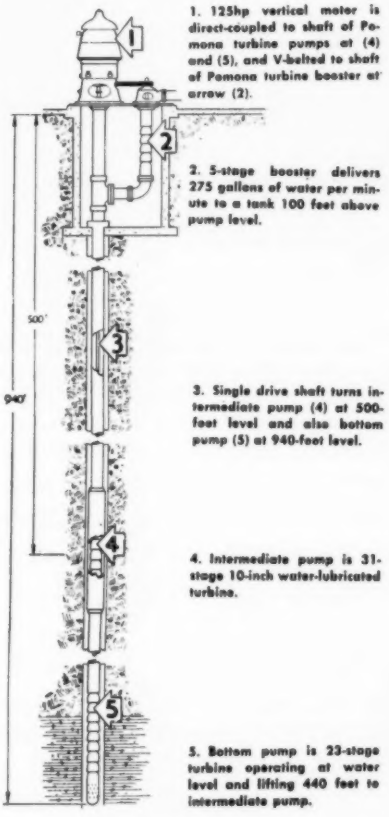
Deep Well Pump

Not all of the water supplies for military uses during the past war were portable units or moderately deep wells for that matter. According to a story in the Jan.-Feb. '46 issue of *Fairbanks-Morse News*, the water supply on Wahiawa in the Hawaiian chain was a thousand feet down through flint-hard volcanic rock. How the F-M engineers solved this problem of water supply is briefly told in the following excerpt from the story in the F-M News:

"The engineers decided on a 59-stage vertical turbine pump to meet the hydraulic requirements. Instead of placing the entire pumping unit at the bottom of the shaft, the system was divided into three smaller units—one at the bottom (some 940 feet from the motor that runs it), another midway and the third at the surface.



1. 125hp vertical motor is direct-coupled to shaft of Pomona turbine pumps at (4) and (5), and V-belted to shaft of Pomona turbine booster at arrow (2).

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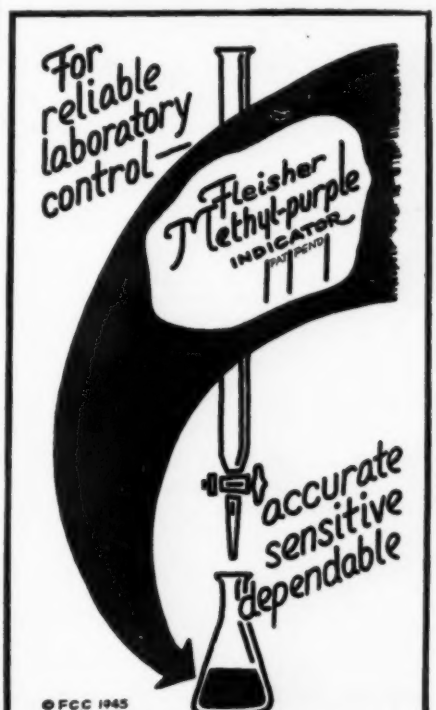

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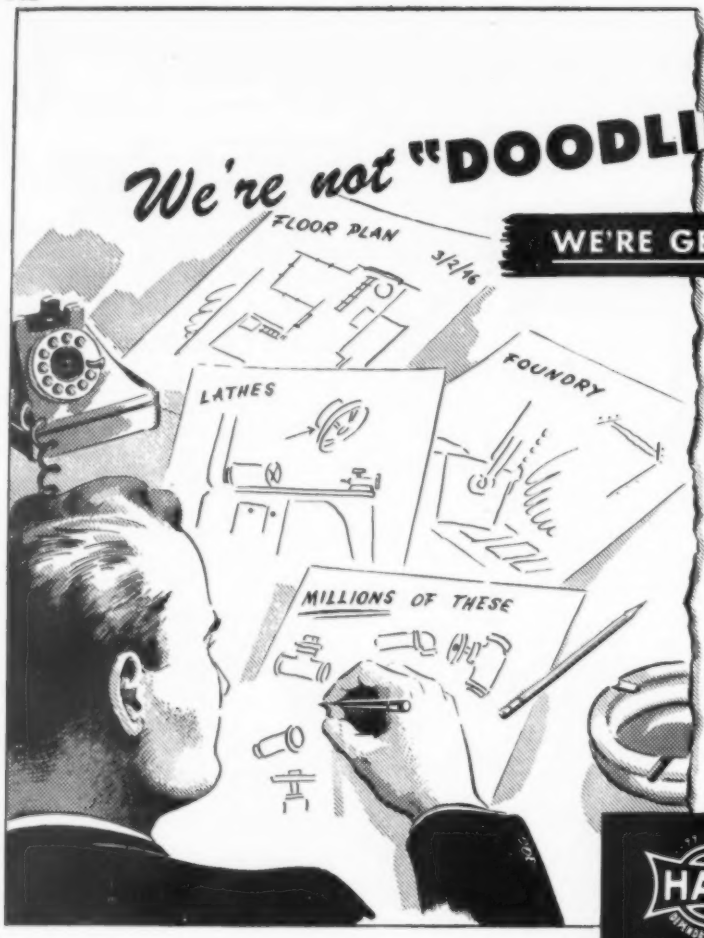

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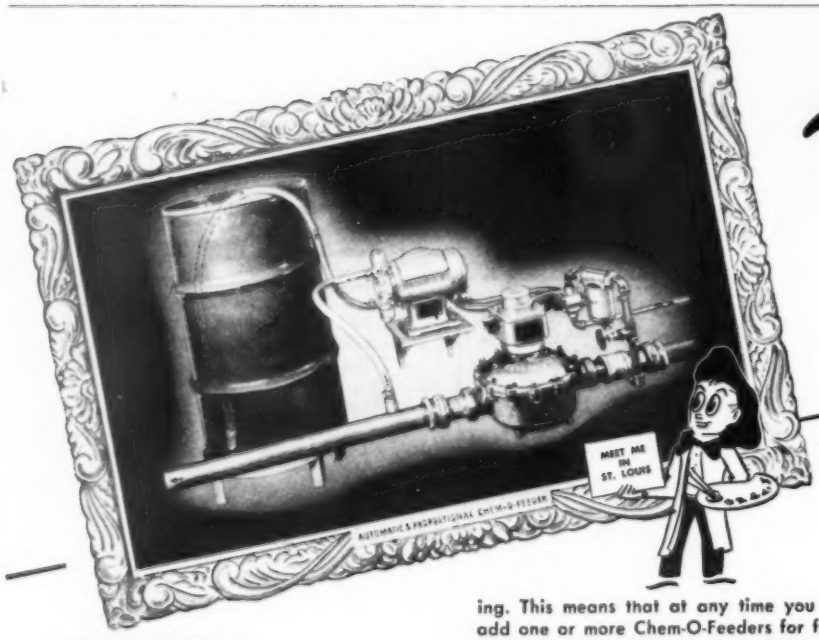

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%Proportioneers% Automatic and Proportional Hydraulically Operated Chem-O-Feeders are used for gravity or other water supplies where the rate of flow may vary from minute to minute. These units inject hypochlorite or other solution in proportion to main flow and are operated by water power from the main itself, or can be furnished to operate by compressed air, steam, etc. The Chem-O-Feeder has a double diaphragm and is of the Treet-O-Control type with pilot valve and gear box mounted on the meter, the feeding unit being separate and only connected to the pilot valve by copper tubing. This means that at any time you can add one or more Chem-O-Feeders for feeding chemicals—such as aqua ammonia for chloramine treatment, aluminum sulphate, soda ash, etc., by merely connecting the new units to the operating control lines without duplicating gear box, pilot valve and control meter. All Treet-O-Control meters are furnished with registered to measure total through put of water.

SPECIFICATION:

Standard, double diaphragm 4D2-5D3 units are for line pressures varying from 10 up to 100 lbs. max. per sq. in. Special low pressure units are available for pressures from 4 up to 15 lbs. max. per sq. in. Chemical delivery is adjustable while unit is operating by means of micrometer stroke length setting, from 0 to approximately 12 CC per stroke. Maximum capacity depends on maximum allowable stroking rate which for hydraulic operation is usually 30 strokes per minute. At 26 strokes per minute, 12 CC per stroke, delivery is approximately 5 gal. per hour or 11.2 lbs. chlorine per day using 1% calcium or sodium hypochlorite solution.

Write for Bulletin SAN-1

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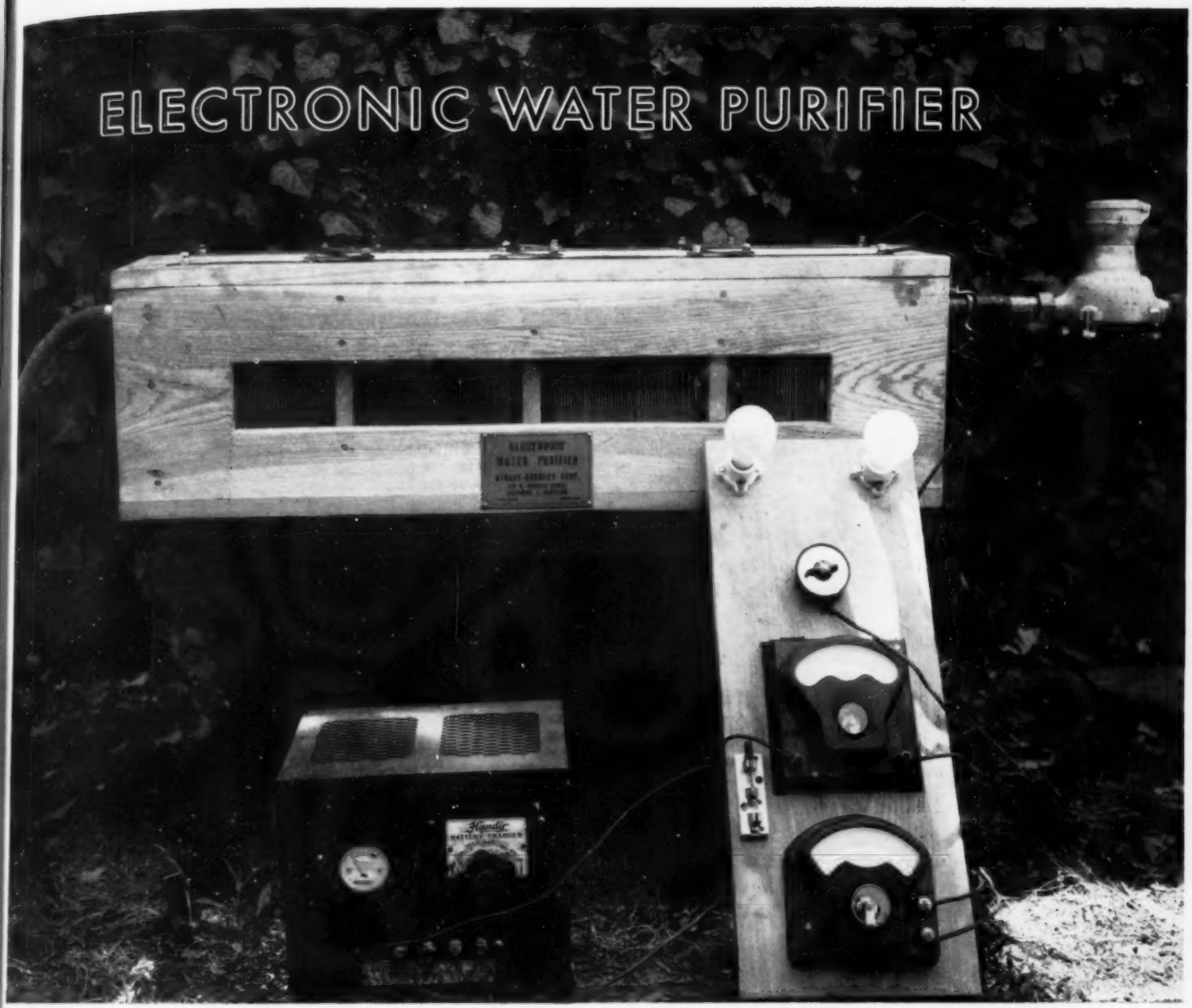

Model A	10,000 gallons per day	$ 650.00
Model B	20,000 gallons per day	$ 950.00
Model C	40,000 gallons per day	$1,400.00
Model D	75,000 gallons per day	$2,500.00

OTHER SIZES—SEND FOR DETAILS

Operates off electric light socket—can be directly connected to pressure or gravity filter. Removes color—turbidity—chlorine demand—operates like a radio—volume control for degree of treatment required. Simple, inexpensive and purifies water to a degree impossible with present methods.

The electronic water purification principle heralded as new development in the art. You will be surprised at the quality water you can produce. Write for details.

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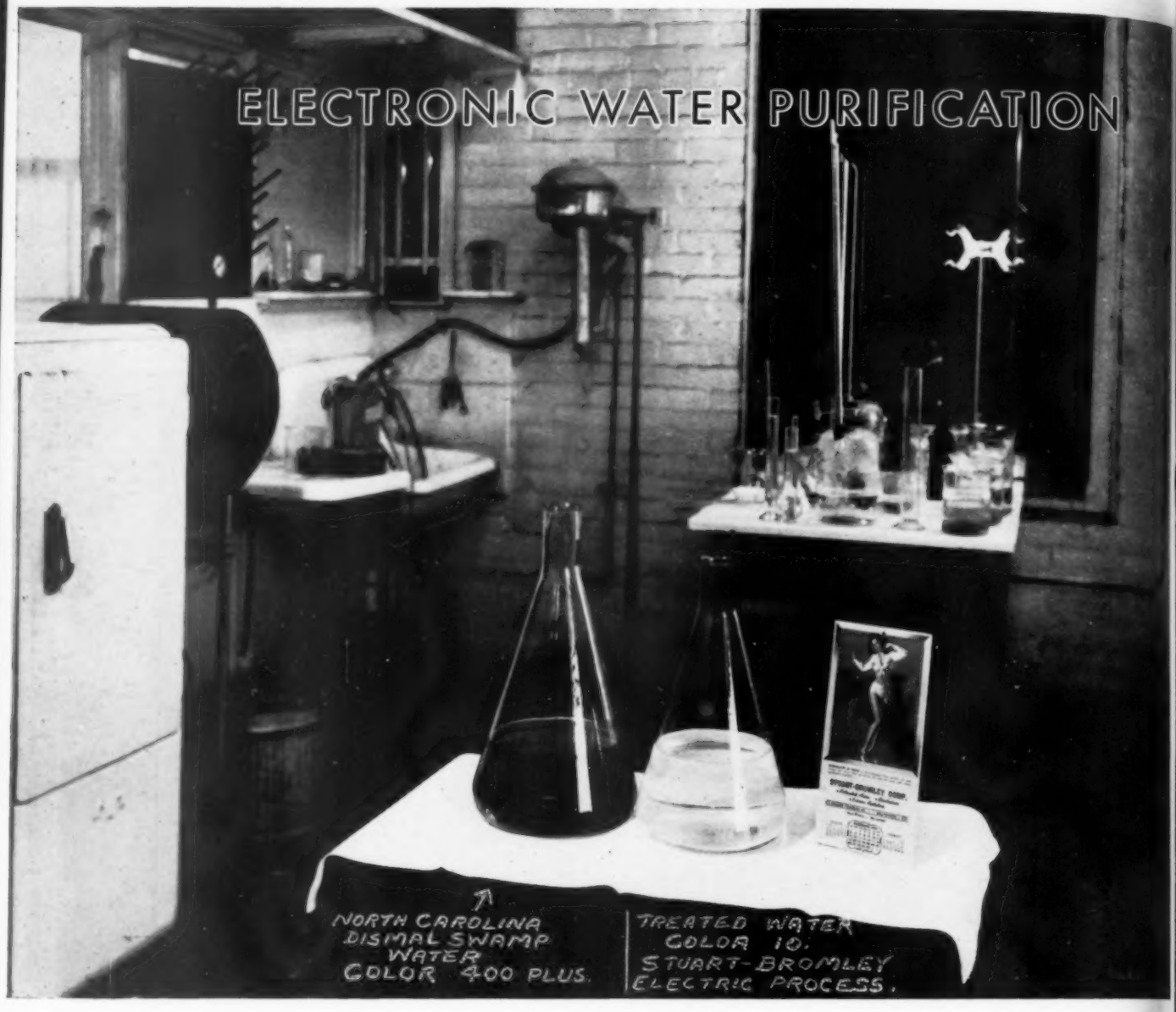
ELECTRONIC WATER PURIFICATION
NORTH CAROLINA DISMAL SWAMP WATER COLOR 400 PLUS.
TREATED WATER COLOR 10. STUART-BROMLEY ELECTRIC PROCESS.

Typical of the many difficult waters in which the Stuart-Brumley Electronic Water Purifier has been used in the above photograph of the North Carolina Dismal Swamp water, which was reduced in color from over 400 to less than 10 in 30 seconds time.

The following analyses show some of the average results obtained in other sections of the country:

LOCATION	COLOR BEFORE	COLOR AFTER	PH BEFORE	PH AFTER
Deep Creek Juniper Water				
Dismal Swamp North Carolina (soft-surface supply)	400	10	5.0	7.5
Norfolk, Virginia—Raw water (soft-surface supply)	90	10	6.8	8.6
Miami, Florida—Raw water (hard-well supply)	70	11	7.3	7.2
Canal Water, Okeechobee Swamp (hard-surface supply)	120	20	7.5	7.4
Lime Soda Softening Plant (softened well supply)	29	14	10.1	8.2

The above analyses were all obtained through 30 seconds contact.

STUART-BRUMLEY CORPORATION 516 N. Charles St., Baltimore 1, Md

Flash Coagulator Units--
Coagulation in 30 Seconds--
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Turbidity Removal--

Just Like Alum
Simplicity of Electricity

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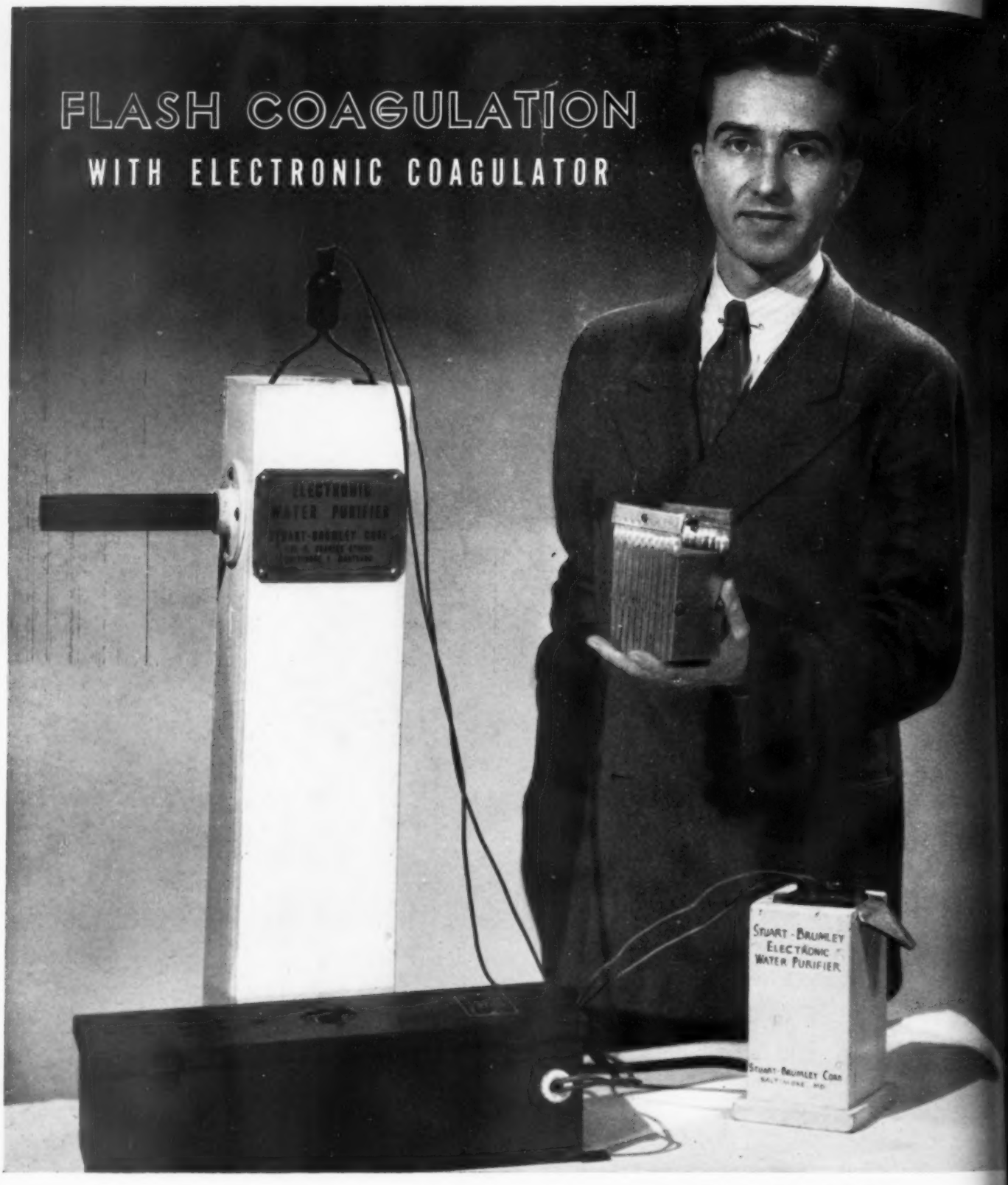

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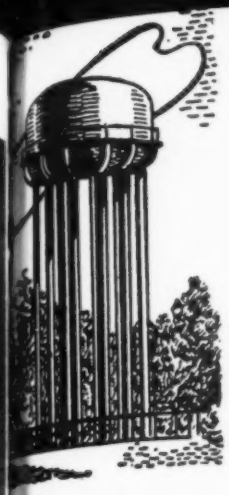

PART 1

WATER SUPPLY

WATER & SEWAGE WORKS

REFERENCE & DATA SECTION

1946

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BULLETIN 300

TYPE MS FLOW RATE METER

Accurately indicates, records and totalizes flow rate. Bell-shaped float automatically extracts the square root of the law of flow and makes possible the direct reading chart —evenly graduated from 0 to maximum. The arm of the recording pen connects directly with the float for inevitable accuracy of transcription and sensitivity to flow change.

BULLETIN 350

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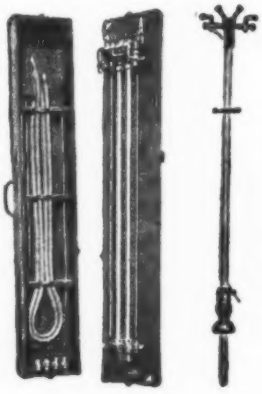
BULLETIN 250

AIR INLET VALVE

Eliminates the possibility of collapse of pipe line walls due to sudden drop in pressure in gravity flow line. The non-collapsible float is buoyed by the water in the line until a condition arises which tends to create a vacuum—then the buoying effect of the water is lost, the float drops from its seat, to admit air and destroy the vacuum.

BULLETIN 125



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Check the operating efficiency of distribution systems, pumps, meters. Panel board, portable, or stationary Recorders, manometers, and pitot tube types of equipment for accurate surveys—at low cost and with small expense—effect definite savings in operating loss.

BULLETIN 50

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BULLETIN 170

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BULLETIN 58

MO & MS METERS • CONTROLLERS • GAUGES • SAND EXPANSION INDICATORS • AIR RELEASE VALVES • AIR & VACUUM VALVES • PITOT EQUIPMENT • SUMMATORS • PRIMARY DEVICES (VENTURI TUBES, PITOT TUBES, ORIFICES, NOZZLES, WEIRS AND FLUMES)

"next to knowing - - - - is knowing where to find knowledge"

Foreword

We take especial pride, as publishers, in presenting this volume—

The 1946 Reference and Data Number of

WATER & SEWAGE WORKS

Prepared by the Editor and Dr. George E. Symons, as Managing Editor, this section presents the equivalent of a data handbook for designing engineers, managers, and operators of water and sewage works.

The information contained herein has been carefully selected from past issues of WATER WORKS AND SEWERAGE (now WATER & SEWAGE WORKS) and other sources named in the text. In addition, considerable effort has been made to present the most economical and modern methods, and the latest tables and charts useful to water and sewage works operators and designers.

Even though supplied to subscribers at no charge beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Reference Section as would be expected in a book devoted exclusively to the same type of material and published separately.

★ ★ ★

Note

In the past we have repeated useful basic data, tables, graphs, etc.—from year to year, chiefly for the benefit of new subscribers; certain other matter was repeated in alternate years; and new material was, of course, added. Thus the subscriber who kept two consecutive Reference and Data issues on file had all of the most important reference material published by WATER WORKS AND SEWERAGE (now WATER & SEWAGE WORKS).

None of the material contained in the 1945 issue is repeated in this issue. Instead, the new material is being augmented with certain basic material selected from the 1944 and earlier issues, with the intent of best serving all of our readers—especially the newer readers.

Nevertheless, in order to have a complete Reference and Data file it will be necessary for the readers to have available not only the current issue but also issues of at least the two years preceding this issue. Therefore for the convenience of the user a consolidated five year index is being incorporated in this issue.

L. H. Enslow

Editor.

INDEX

FOR THE INDEX TO THE REFERENCE AND DATA MATERIAL, AND THE INDEX TO ADVERTISERS, SEE THE REAR OF THIS SECTION

CLASSIFIED INDEX of PRODUCTS

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(See Blowers, Air)

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(See Compressors, Air)

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Hagan Corp., The, Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago 9, Ill.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., Bessemer Bldg., burgh 30, Pa.

BOOKS, TECHNICAL
Theo. Audel & Co., 49 W. 23rd St., New York 10, N. Y.
John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER
(See Valve Boxes; Meter Boxes)

BRASS GOODS
(See also Pipe, Brass)
American Brass Co., Waterbury, Conn.
Bridgeport Brass, Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

BREATHING APPARATUS
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUTTERFLY VALVES
(See Valves, Butterfly)

CALCIUM HYPOCHLORITE
(See also Bleaching Powder)
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

CALGON
(See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

CARBON-ACTIVATED
(See Activated Carbon)

CARBONATORS (Recarbonation).
Carborundum Co., Perth Amboy, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Vogt Mfg. Co., Louisville, Ky.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Climax Engineering Co., Clinton, Iowa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Fort Pitt Steel Castings Div., H. K. Porter Co., McKeesport, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hunt, Rodney, Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe)

CATCH BASIN CLEANERS
Champion Corp., Hammond, Ind.

CATHODIC PROTECTIVE SYSTEMS
Dow Chemical Co., Midland, Mich.
Electro Rust-Proofing Co., 1026 Wayne Ave., Dayton, Ohio.
Johnston & Jennings Co., Rusta Restor Div., 877 Addison Rd., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hood Chemical Co., 450 W. 31st St., New York City.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT GUN
Cement Gun Co., Allentown, Pa.

CEMENT PIPE
(See Pipe, Concrete)

CEMENT LINED PIPE
(See Pipe)

CEMENT LINING OF PIPE
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL, CONVEYING EQUIPMENT
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold, 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHLORIDE OF LIME (Chlorinated Lime)
(See Bleaching Powder)

CHLORINATORS
(See also Hypochlorinators)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., Sixth & Byrd, St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

CHLORINE DIOXIDE
(See Sodium Chlorite)

CHLORINE, LIQUID
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Diamond Alkali Co., Pittsburgh, Pa.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

CHLORINE CONTROL EQUIPMENT
(See Residual Chlorine Control)

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

CLARIFIERS, SEWAGE AND WATER
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hardinge Co., Inc., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

CLEANERS, AIR INTAKE
Burgess-Manning Co., 2815 W. Roscoe, Chicago, Ill.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANING SEWAGE MAINS
(See Sewer Cleaning Equipment and Service)

CLEANING WATER MAINS
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Atlas Mineral Products Co., Mertztown, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corporation, Etc.)
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COLLECTORS (Sludge)
(See Sludge Collectors)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., York 18, N. Y.

COMMINUTORS
(See Grinders also)
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Lapp Insulator Co., Leroy, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Co. Bldg., Philadelphia 2, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
Allis Chalmers Co., Milwaukee, Wis.
Clayton Mfg. Co., Alhambra, Calif.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Sullivan Machinery Co., Michigan City, Indiana.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS
Gardner-Denver Co., Quincy, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Sullivan Machinery Co., Michigan City, Indiana.

CONCRETE CONTROL
Scientific Concrete Service Corp., McLachlen Bldg., Washington, D. C.

CONCRETE HARDENER
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

CONCRETE PIPE
American Concrete Pipe Assn., 33 W. Grand Ave., Chicago 10, Ill.
Lock-Joint Pipe Co., P. O. Box 269, East Orange, N. J.

CONDENSERS (Steam)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTRACTORS (Water & Sewage Works)
Ambursen Engineering Corp., 295 Madison Ave., New York, N. Y.
Cement Gun Co., P. O. Box 424, Allentown, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
The Eimco Corp., 634 S. 4th West St., Salt Lake City 8, Utah
Food Machinery Corp., 3075 Twelfth St., Riverside, Calif.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Co., 3409 E. 18th St., Kansas City, Mo.

COOLING TOWERS
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

COPPERAS (Sulphate of Iron)
Innis-Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York 6, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dow Chemical Co., Midland, Mich.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

COUPLINGS & CONNECTIONS, PIPE
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
A. M. Byers Co., Pittsburgh, Pa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.

COUPLINGS, FLEXIBLE
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Div., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 220 S. Belmont Ave., Indianapolis 6, Ind.
Lombard Governor Corp., Ashland, Mass.
Peerless Pump Division, Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.

COVERS, HANDHOLE, MANHOLE, SAMPLING
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
United Concrete Form Products Co., 5243 W. 25th Pl., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CULVERT CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CULVERT PIPE
(See Pipe, Culvert)

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

DECHLORINATING EQUIPMENT AND CHEMICALS
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

DE-MINERALIZATION (Water)
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES & TUBES
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DIGESTER EQUIPMENT (Sludge)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison St., Pittsburgh, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hardinge Co., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Sewage Filter)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

DRILLING & BORING EQUIPMENT
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Cal.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR
Johnson Gear Co., Berkeley, Calif.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 40th and Harrison St., Pittsburgh, Pa.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

EJECTORS, PNEUMATIC OR STEAM (For Sewage and Sludge)
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICAL CONTROL EQUIPMENT
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNITS
Climax Engineering Co., Clinton, Iowa.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y. (Gasoline Driven Portable.)
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DIESEL
Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DUAL FUEL
Cooper Bessemer Corp., Mt. Vernon, O.
Worthington Pump & Mach. Corp., Harrison, N. J.

ENGINES (Gas & Gasoline)
Buffalo Gasolene Motor Co., Buffalo 13, N. Y.
Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SLUDGE GAS
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Climax Engineering Co., Clinton, Iowa.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATING
Jeffrey Mfg. Co., The, 968-99 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FEED WATER HEATERS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

FERRIC CHLORIDE
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa. (Liquid.)
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULFATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
L. A. Salomon & Bro. 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

FERROUS SULFATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

FIBRE PIPE
(See Pipe, Fibre)

FILTER ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

FILTERING EQUIPMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
R. D. Cole Mfg. Co., Newnan, Ga.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hardinge Co., Inc., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Norwood Engr. Co., 25 N. Maple St., Florence, Mass.
Oliver United Filter, Inc., New York City.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Sanequipment Engr. Co., 2843 Whitewood Drive, Ann Arbor, Mich.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Worthington Pump & Machinery Corp., Harrison, N. J.

FILTER PLATES AND TUBES
Carborundum Co., Perth Amboy, N. J
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER UNDERDRAINS, SEWAGE
The American Well Works, Aurora, Ill.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

FILTER UNDERDRAINS, WATER
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hardinge Co., Inc., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., York 18, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

FIRST AID KITS
Mine Safety Appliance Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

FISH SCREEN
Electric Fish Screen Co., Hollywood 45, Calif.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
American Smelting and Refining Co., 120 Broadway, New York City.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

FITTINGS, TEES, ELLS, ETC.
American Cast Iron Pipe Co., Birmingham, Ala.
Bridgeport Brass Co., Bridgeport 2, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
(See Mixers & Mixing Equipment)

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart-Brumley Corp., 516 N. Charles St., Baltimore, Md.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW RECORDERS
(See Rate of Flow Recorders)

FLOW REGULATORS
(See Rate of Flow Controllers)

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

GAGES (Liquid Level, Pressure Recording)
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y. (Pressure).
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Wallace & Tiernan Co., Inc., Newark, N. J.

GARBAGE GRINDERS
(See Grinders)

GAS DIFFUSERS
The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS ENGINES
(See Engines, Gas & Gasoline)

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS HOLDER INSPECTION SERVICE
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS INDICATORS AND DETECTORS
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

GAS MASKS (Cannister and Hose)
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

GAS PURIFICATION
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GATES, ROLLER
Hunt, Rodney, Machine Co., Orange, Mass.

GATES, SHEAR
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

GATES, SLUICE
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate)

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES
(See Engine Generating Units)

GOOSENECKS
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church New York 7, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GREEN SAND (Zeolite)
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
General Electric Co. (household), Bridgeport, Conn.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 Hunting Park Ave., Philadelphia, Pa.
H. K. Porter Co., Inc., 49th and Harrison Sts., Pittsburgh, Pa.

GRIT CHAMBER EQUIPMENT
The American Well Works, Aurora, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

GUNITING CONTRACTING
Cement Gun Co., P. O. Box 424, Allentown, Pa.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Pa.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Sullivan Machinery Co., Michigan City, Indiana.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRANTS (Fire)
The Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
(See Valves, Gate)

HYDROGEN ION EQUIPMENT
(See pH Test Equipment.)

HYPO-CHLORINATORS
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark 1, N. J.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Morse Boulger Destructor Co., 205 E. 42nd St., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

INSTRUMENTS (Surveying, Hydrographic and Navigation)
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Oregon.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULFATE
(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS
Atlas Mineral Prod. Co., Mertztown, Pa.
J. H. Grancell, 1601 E. Nadeau St., Los Angeles 1, Calif.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Rensselaer Valve Co., Troy, N. Y.
Servicised Products Corp., 6061 West 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, MECHANICAL, FLEXIBLE
American Cast Iron Pipe Co., Birmingham, Ala.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

LABORATORY APPARATUS AND REAGENTS
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Fleischer Chem. Co., P. O. Box 616, Washington 4, D. C.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Nat'l Technical Labs, Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

LOCATORS, BOX, PIPE AND VALVE
(See Respective Headings.)

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2320 N. Alameda St., Compton, Calif.

MEASURING INSTRUMENTS
(See Instruments.)

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.
Badger Meter Co., Milwaukee, Wis.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Foxboro Co., Foxboro, Mass.
Ford Meter Box Co., Wabash, Ind.
Meter Specialty Co., 1332 N. 7th St., Memphis, Tenn.
Mueller Co., Decatur, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Illinois.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co. E and First Sts., South Boston 21, Mass.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Worthington - Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Invanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
American Meter Co., 60 E. 42nd St. New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Neptune Meter Co., 50 W. 50th St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington - Gamon Meter Co., Newark, N. J.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS AND MIXING EQUIPMENT
(Chemical, Water, and Sewage)
The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Bimco Corp., 634 S. Fourth West St., Salt Lake City 8, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St. New York 18, N. Y.
H. K. Porter Co., Inc., 1032 Oliver Bldg., Pittsburgh 22, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.

MOTORS, ELECTRIC
Allis - Chalmers Co., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

NIPPLES, PIPE
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
A. M. Byers Co., Pittsburgh, Pa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Co. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York, N. Y.

NO-OX-ID
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Bean-Cutler Div'n, Food Machinery Corp., 217 W. Julian St., San Jose 5, Calif.
Chain Belt Co., Milwaukee, Wis.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

OPERATING TABLES (Filter)
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

pH TEST EQUIPMENT
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
Northrop & Co., Inc., 50 Church St., New York, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

PIPE AND TANK COATINGS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE BENDING MACHINES
Hays Mfg. Co., Erie, Pa.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 4th Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Hunt, Rodney, Machine Co., Orange, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Centriline Corp., 140 Cedar St., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Preload Corp., 420 Lexington Ave., New York City.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LINING OF
Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 420 Lexington Ave., New York City.
Tate Pipe Linings, Inc., 47 Haverhill St., Andover, Mass.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.

PIPE, COPPER, BRASS AND BRONZE
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PIPE, CORRUGATED
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Ridge Tool Co., Elyria, Ohio.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE, DRILLS, JACKS AND PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE ENAMELS, PROTECTIVE —COAL TAR
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, FELT WRAPPING
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE, FIBRE
Fibre Conduit Co., Orangeburg, N. Y.

PIPE FITTINGS (See Fittings Pipe)

PIPE—GALVANIZED, LIGHT-WEIGHT (Quick Coupling, Transportable for Conveying Water)
Armco Drainage Products Assoc., Middletown, Ohio.
Champion Corp., Hammond, Ind.

PIPE, HARD RUBBER LINED
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

PIPE JOINT COMPOUNDS
(See Jointing Compounds.)

PIPE JOINTS (Mechanical)
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.
R. D. Wood & Co., 400 Chestnut St., Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS
Atlas Mineral Products Co., Mertztown, Pa.
Hays Mfg. Co., Erie, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

PIPE, LEAD LINED
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.

PIPE LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Frank N. Blake, North Adams, Mass.
Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PIPE PUSHERS
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Hydraulic Supply Co., Ltd., 116 New Montgomery St., San Francisco, Calif.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Am. Concrete Pipe Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete.)
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Fibre Conduit Co., Orangeburg, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, STEEL (All Types)
Armco Drainage & Metal Products, Inc., Middletown, O.
American Locomotive Co., Alco Products Div., 30 Church St., New York 8, N. Y.
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

PIPE TAPPING MACHINES
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TEST PLUGS
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
The Richmond Fdry. & Mfg. Co., Richmond, Va.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)
Ridge Tool Co., Elyria, Ohio.
Tucker Co., Inc., 75 Murray St., New York, N. Y.

PIPE, VITRIFIED CLAY
(See Vitrified Clay Pipe and Products.)

PIPE, WRAPPING
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE, WROUGHT IRON
A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

PITOT TUBES
Pitometer Company, 50 Church St., New York City.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland, Ore.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.

PNEUMATIC TOOLS
Sullivan Mach. Co., Michigan City, Ind.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

PRESSURE REGULATORS
(See Regulators, Pressure)

PROPORTIONING EQUIPMENT
(See Chemical Feed and Proportioning Equip.)

PUMP PRIMERS
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, ACID-HANDLING
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Pumps, Peerless Pump Division, Inc., Quincy, Illinois.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, New York 18, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, CELLAR DRAINER
(See Pumps, Sump)

PUMPS, CENTRIFUGAL
Allis-Chalmers Co., Milwaukee, Wis.
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
A. D. Cook Co., Inc., Lawrenceburg, Indiana.
Dayton-Dowd Pumps, Peerless Pump Division, Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gardner-Denver Co., Quincy, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th & Harrison Sts., Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
A. D. Cook Co., Inc., Lawrenceburg, Indiana.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D. St., South Boston, Mass.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Northrop & Co., Inc., 50 Church
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.

PUMPS, HYDRAULIC
Ross Valve Mfg. Co. Inc., Troy, N. Y.

PUMPS, JETTING
Ralph B. Carter Co., 53 Park Pl., New York N. Y.
Gorman-Rupp Co., Mansfield, Ohio.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Ave. 26, Los Angeles 31, Calif.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Station, Memphis 8, Tenn.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Div., H. K. Porter Co., 49th & Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Northrop & Co., 50 Church St., New York 7, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.

Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE

Allis-Chalmers Co., Milwaukee, Wis.
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., Hamilton, Ohio.
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE

Allis-Chalmers Co., Milwaukee, Wis.
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 18, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP (AND CELLAR DRAINER)

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps Inc., Hamilton, Ohio
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div., H. K. Porter Co., 49th & Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
A. D. Cook, Inc., Lawrenceburg, Indiana.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, VACUUM

Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps Inc., Hamilton, Ohio.
Oliver United Filters Inc., 33 W. 42nd St., New York 18, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

RATE OF FLOW CONTROLLERS

American Meter Co., 60 E. 42nd St., New York City.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
The Foxboro Co., Foxboro, Mass.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

RATE OF FLOW RECORDERS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
The Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
Northrop & Co., 50 Church St., New York 7, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS

Mueller Co., Decatur, Ill.
Ridge Tool Co., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

RECEIVING COIL, AMPLIFYING

Frank N. Blake, 15 Highland Ave., North Adams, Mass.

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE (Water and Gas)

American Meter Co., 60 E. 42nd St., New York City.
American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Clayton Mfg. Co., Alhambra, Cal.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 6, Ill.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue, Los Angeles 26, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESIDUAL CHLORINE CONTROL APPARATUS

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

RESPIRATORS

Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

RUST PREVENTION (Tanks, Pipe Lines, Submerged Metal)

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dow Chemical Co., Midland, Mich.
Electro Rust-Proofing Corp., 1026 Wayne Ave., Dayton 10, Ohio. (Cathodic Protection)
The Johnston & Jennings Co., Rusta Restor Div., 877 Addison Rd., Cleveland, O.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

SADDLES, PIPE

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

SAFETY EQUIPMENT (For Workers)

Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

SAMPLERS AND SAMPLING TABLES

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

SCALES, SLUDGE CONVEYOR

Builders-Providence, 9 Codding St., Providence, R. I.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SCREENS, SAND, GRAVEL AND STONE

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SCREENS, VIBRATING

Link Belt Co., 307 N. Michigan Ave., Chicago 1, Illinois.

SCREENS, WATER WELL

Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Nat'l Clay Pipe Mfrs. Inc., 111 W. Washington St., Chicago, Ill.

SEPTIC TANKS (Vitrified Clay)

Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

SERVICE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
United Concrete Form Products Co., 5243 W. 25th Place, Chicago, Ill.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Drake Mfg. Co., 1461 Belfield Ave., Philadelphia, Pa

Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

SEWAGE SLUDGE INCINERATOR

Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Morse Boulger Destructor Co., 216 East 45th St., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWER CLEANING EQUIP. AND SERVICE

Champion Corp., Hammond, Ind.
J. C. Fitzgerald, P. O. Box 289, Coral Gables 34, Fla.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

SEWER PIPE

(See Pipe, Sewer)

SEWER PIPE JOINTS

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER PIPE LOCATORS

Frank N. Blake, North Adams, Mass.

SEWER RODS

Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

SILENCERS, ENGINE, INTAKE, EXHAUST AND AIR INTAKE

Burgess-Manning Co., 2815 W. Roscoe, Chicago, Ill.

SIPHONS (Sewage)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City. (Alternating.)
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SLEEVES, PIPE REPAIR

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (Valve)

Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg., Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS

(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID

Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Hardinge Corp., York, Pa.

SLUDGE GAS ENGINES

(See Engines, Sludge Gas)

SLUDGE PUMPS

(See Pumps, Sludge)

SNUBBERS

(See Silencers.)

SODA ASH

Diamond Alkali Co., Pittsburgh, Pa.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE

Dearborn Chemical Co., 310 Michigan Ave., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.

SODIUM BISULPHITE

General Chemical Co., 40 Rector St., New York, N. Y.

SODIUM CHLORITE

Mathieson Alkali Works, 60 East 42nd St., New York 17, N. Y.

SODIUM PHOSPHATES (Glassy)

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

SODIUM SILICATE

Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS

(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION

De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPRINKLING FILTER EQUIP.

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS

(See Filter Underdrains, Sewage.)

STACKS

Cement Gun Co., P. O. Box 424, Allentown, Pa.
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Johns-Manville Co., 22 E. 40th St., New York City.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

STANDPIPES

(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION

(See Cathodic Protection Process.)

STERILIZING WATER MAINS

(See Water Main Sterilization)

STIRRERS (Laboratory)

Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.
H. K. Porter Co., Inc., 1932 Oliver Bldg., Pittsburgh 22, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

STOKERS

Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston & Jenninga Co., 877 Addison Rd., Cleveland, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

STORAGE TANKS (See Standpipes and Tanks)

STRAINERS, SUCTION

Barrett, Haentjens & Co., Hazleton, Pa.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA

(See Filter Alum)

SULPHUR DIOXIDE (Liquid)

Great Western Div., Dow Chemical Co., 310 Sansome St. San Francisco, Calif.
Virginia Smelting Co., West Norfolk, Va.

SUPERNATANT LIQUOR (Selectors and Treaters)

Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SWITCHBOARDS

Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Climax Engineering Co., Clinton, Iowa.
Johns-Manville, 22 East 40th St., New York, N. Y.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

TANKS AND STANDPIPES (Steel)

Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
H. K. Porter Co., 49th & Harrison, Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

TANKS, RUBBER LINED

Atlas Mineral Products Co., Mertztown, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

TAPPING MACHINES

Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

TASTE & ODOR REMOVAL CHEMICALS

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville, Fla.
Cliffs Dow Chemical Co., Marquette, Mich.
Darco Corp., 60 E. 42nd St., New York 17, N. Y.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Tank & Mfg. Co., East Chicago, Ind.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Mathieson Alkali Works, Inc., New York, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
L. A. Salomon & Bros., 216 Pearl St., New York City.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

TESTERS (Water Meter)

Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., E and 2nd Sts., South Boston 27, Mass.
National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

THICKENERS (Sludge)

Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

TOOLS, PIPE

(See Pipe Tools.)

TOOLS, PNEUMATIC

Schramm, Inc., Westchester, Pa.
Sullivan Machinery Co., Michigan City, Ind.

TRAPS, DRIP, FLAME, SEDIMENT

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago, Ill.
Vaper Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRENCHING EQUIPMENT

Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

TRICKLING FILTER UNDERDRAINS

(See Filter Underdrains.)

TRITURATORS

(See also Grinders)
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES

Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING

Jeffrey Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC

De Laval Steam Turbine Co., Trenton, N. J.
Hunt, Rodney, Machine Co., Orange, Mass.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

TURBINES, STEAM

De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
Chapman Valve Mfg., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE BOX LOCATORS

Northrop & Co., Inc., 50 Church St., New York City.

VALVE OPERATOR

(See Gate Valve Operator)

VALVES

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange Mass.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, BUTTERFLY

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Hunt, Rodney, Machine Co. Orange, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.

VALVES, CHECK

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrup & Co., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE

Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, DIAPHRAGM

McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

VALVES, EMERGENCY TRIP

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.

VALVES, FLAP

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Ludlow Valve Mfg., Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Northrup & Co., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Bros. Mfg. Co., 1402 W. Main St., Louisville 3, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, LUBRICATED PLUG

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Merco-Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.

VALVES, MOTOR OPERATED

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div. Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RELIEF

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Johns-Manville, 22 E. 40th St., New York, N. Y.
S. Morgan Smith, York, Pa.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Barrett, Haentjens & Co., Hazleton, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
The A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Co., 9 Codding St., Providence 1, R. I.

VENTURI TUBES

Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St. Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland, Ore.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATING SCREENS (Liquid)

Link Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.

VIBRATORS, ELECTRO-MAGNETIC

Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VISES, PIPE

Ridge Tool Co., Elyria, Ohio.

VITRIFIED CLAY PIPE AND PRODUCTS

Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

WASTE GAS BURNERS

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagent.)

WATER HAMMER ARRESTERS

Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
S. Morgan Smith Co., York, Pa.

WATER MAIN STERILIZATION (A Service)

Luther & Wood, 310 Chandler Bldg., 1427 Eye St., N. W., Washington, D. C.

WATER LEAK, LOCATING INSTRUMENTS

Fisher Research Lab., 1961-63-65 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

WATER MAIN CLEANING

Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York 7, N. Y.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., Cleveland, O.
Johns-Manville, 22 E. 40th St., New York City.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT

The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg., Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Omega Machine Co., 3400 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER STABILIZATION (Chemicals for)

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

WATER SUPPLY CONTRACTORS

(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
The Permutit Co., 330 W. 42nd St., New York 19, N. Y.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER TREATMENT PLANTS (Steel)

Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

WATER WASTE SURVEYS

Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

WELLS, COMPLETE

Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 5, Tenn.

WRAPPING, PIPE

(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., Bradford, Pa.

WROUGHT IRON (Pipe, Gates, Bars, Etc.)

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS

(WHERE TO FIND IT)

By LINN H. ENSLOW
Editor, "Water & Sewage Works"

IT goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manuals published by the American Water Works Association — "Water Works Practice," the "Purification Manual" and the "Accounting Manual."

Text books, manuals, hand-books, journals, and catalogs are named alphabetically in the attached list of recommended reference works for water and sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists called on to offer suggestions in making up a set of reference works. It is an attempt to recommend those books of greatest usefulness.

LIST NO. 1—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md.	
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Copper Sulphate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Elements of Water Supply Engineering (2nd Ed.)	John Wiley & Sons, New York City	Waterman
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Handbook of Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 3rd Edition ($3.00)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co., Brooklyn 2, N. Y.	A. A. Hirsch
Manual for Water Works Operators ($3.00)	Texas Water Works & Sewerage Short School, Austin, Tex.	Various
Manual of Water Quality and Treatment	Am. Water Works Assn., New York City	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Modern pH Control (F)	W. A. Taylor Co., Baltimore, Md.	
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracy
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Public Water Supplies—4th Ed. ($6.00)	John Wiley & Sons, New York City	Turneaure & Russell
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A. and A. W. W. A., New York City	Various
Technical Bulletin on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Treatment of Municipal and Industrial Waters—Tech. Bul. No. 8 (F)	The Solvay Process Co., New York City	
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md.	Hopkins
Water Purification for Plant Operators ($2.50)	McGraw Hill Co., New York City	Norcom and Brown
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Works Engineering in Disaster (F)	O.C.D. Pub. No. 2022, Washington, D. C.	McCallum
Water Works Handbook ($7.00)	McGraw Hill Co., New York City	Flynn, Weston & Bogert
Water Supply & Treatment, 3rd Ed. ($0.75)	National Lime Assn., Washington, D. C.	Hoover

(F) Available as Free Publication at this writing.

Journals and Magazines (Applies to Lists 1 and 2)

Journal and Monographs of the American Waterworks Association
Journal of the New England Water Works Association
Current Water Works Technical Magazines and Trade Papers

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Applied Hydraulics ($6.50)	John Wiley & Sons, Inc., New York City	Herbert Addison
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Data Book on Design for Civil Engineers ($7.50)	John Wiley & Sons, Inc., New York City	Elwyn E. Seelye

(Continued on page R-14)

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS
(In addition to List No. 1)

Books	*Publishers*	*Authors*
Deep Well Drilling	The Gulf Publishing Co., Houston, Tex	Walter H. Jeffery
Design of Dams ($5.00)	McGraw-Hill Book Co., New York City	Hanna and Kennedy
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Geomorphology	McGraw-Hill Book Co., Inc., New York City	A. K. Lobeck
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Handbook of Applied Hydraulics	McGraw-Hill Co., New York City	Various
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Hydraulic Measurements	John Wiley & Sons, Inc.	Addison
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
pH and Its Practical Application ($3.50)	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Physics of the Earth IX	McGraw-Hill Book Co., Inc., New York City	Oscar E. Meinzer
Plumbing Engineering ($3.50)	Pittman Publishing Co., New York	Cleverdon
Pocket Companion (nominal)	Carnegie-Steel Corp., New York City	
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Summary of Census Data on Water Treatment Plants in the United States	Am. Water Works Assn. Reprint	U. S. Pub. Health Service
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
The Hardy Cross Method of Distribution System Design.	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler

****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.
For Journals see list No. 1.

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Chlorination in Sewage Treatment****	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Laboratory Manual of Water and Sewage Analysis 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Manual of Sewage Works Operation****	New Jersey Sewage Expt. Sta., New Brunswick, N. J.****	
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Principles of Sewage Treatment ($0.50)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Sewage Treatment ($3.00)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.

Journals and Magazines

Sewage Works Journal—(Official publication, Sewage Works Federation)
Current Sewage Works Magazines

LIST NO. 4—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**
(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Municipal and Rural Sanitation, 3rd Ed.	Mc-Graw-Hill Book Co., Inc., New York City	Ehlers & Steel
Sewage Trade Waste Treatment	Govt. Printer, Adelaide, Australia	Henry J. N. Hodgson
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewerage and Sewage Treatment—2nd Ed. ($4.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	

(F) Available as Free Publication at this writing.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.
***Note*—Sewage works men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

GUIDES AND CHECKS ON WATER WORKS OPERATION

By LOUIS R. HOWSON
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EVERY golf course has its "par" and every confirmed golfer his "handicap." The object of both is to improve the player's performance.

In the water works field the major holding companies have developed a system of yardsticks or checks upon the operations of their respective properties, individually adapted to the variations in service conditions, equipment and other facilities available for the service. These checks undoubtedly pay dividends for those companies and are an important part of the holding companies' service to their operating properties. A very small percentage of all the water works systems in the country, however, are under holding company operation, and it is for the purpose of providing some general yardsticks for the large number of independently operated systems that this discussion is written. These yardsticks must necessarily be general but material deviations from the general range should flag the operator's attention and will usually indicate the desirability of investigating the causes for the lack of conformity. In most cases this will result in improved operation.

Starting with the widest generalities, it may be stated that the over-all number of employees in the operating and maintenance departments of the average water works will be within the range of one employee for each 800 to 1,200 population for cities of about 25,000 population, becoming less with greater populations and usually averaging one employee to each 1,500 to 2,000 population for cities in the million population bracket. Obviously, individual cities are affected by remote and widely scattered sources of supply, pumping stations, purification plants, etc., but the above figures are sufficient to indicate a very general range in total personnel.

Water works revenues in other than the more arid sections of the country normally range from $5.00 to $7.00 per capita per year. Operating expenses other than depreciation normally average approximately $2.00 per capita, with a range of from $1.25 to $3.00 per capita. The investment in property will average around $70 per capita and the annual depreciation charge will vary from approximately 75c per capita average for private water works to $1.25 per capita on municipally operated water works where the retirement reserve is largely utilized for new construction.

From these generalizations more specific reference will be made to some items of water works operation and their costs in which economies can most frequently be effected.

Pump Efficiency

Too few operators have information relative to the operating efficiency of their pumping equipment or what constitutes efficiencies practicable of attainment. In recent years there has been a noticeable trend toward motor-driven centrifugal pumping equipment, with which the following discussion is concerned.

Deep Well Turbines

Deep well turbine pumps are most frequently of low efficiency, due to the fact that they are usually installed from 100 to 300 ft. below ground surface, are out of sight and costly to remove for inspection. Over the years, however, they have been developed to a high degree of reliability.

It is now practicable to secure new equipment of this type in capacities of 700 gpm. and upward, which will operate at from 67 to 70 per cent or higher wire-to-water efficiency. It is the author's belief, based upon personal observation, that a large proportion of deep well turbine equipment is operating at so low an overall efficiency that its replacement is warranted. On a recent investigation of a water supply which had three deep wells in the Chicago area, efficiency tests showed that all three pumping units had over-all efficiencies of less than 50 per cent. One unit, having a 1000 gpm. delivery at a 140-ft. head, and testing 43 per cent efficient, was removed from the well for inspection. It was found that the pump was badly worn and that some of the shaft bearings and column protector pipe were in poor condition. The defective bearings, shafting and pipe were replaced and new pump bowls purchased, involving a total expenditure of approximately $1,100. The saving in power due to the more efficient unit amounted to about $950 per year, sufficient to pay about 85 per cent annual return on the investment in the new unit. It would have been possible to purchase a new set of bronze pump bowls without the shafting and pipe for this unit for $535, and to increase the over-all efficiency from 43 to 68 per cent. The cost of the new bowls alone would have been fully recovered in about eight months' operation with the higher efficiency unit.

The pump bowls in at least one of the other wells are scheduled for replacement the next time the pump is pulled for any reason. In the meantime, the new, more economical unit is performing the major part of the pumping.

In another northern Illinois city two deep well 600-gpm. turbines, operating at approximately 250-ft. head, were recently tested. The wire-to-water efficiencies were 40.6 and 37.2 per cent, respectively. One of these units is now being replaced with an entirely new 1,000-gpm. unit with a guaranteed over-all efficiency of 67.5 per cent. The total cost of the motor, pump and 300 ft. of discharge column and shafting was 7,100. The saving in power will pay for the entire cost of this unit in a little over two years' time. The old unit is being rehabilitated for use as a spare.

As a check on the efficiency of operation of deep well turbines, it may be stated that the average deep well turbine installation should use somewhere between 450 and 500 kwhr. per mil.gal. pumped 100 ft. higher. Each 5 per cent loss in efficiency, with power purchased at 1c per kwhr. and assuming substantially continuous operation, will cost approximately $150 per year per million gallons pumped 100 ft high. The correction of but a 5 per cent loss in efficiency will usually pay at least 25 per cent return on the cost of new bowls or the rehabilitation of the old equipment.

From the above, the following conclusions are indicated:

1. All deep well turbines should be frequently checked for wire-to-water efficiency.

TABLE I

gpm.	Approx. Over-all Eff., %	Annual Cost of Power @ 1c/kwhr. Operating 75% of Time	Approx. Price of Pump and Coupling for 200-Ft. Head	Annual Cost of 5% Loss in Eff. @ 1c/kwhr.	Annual Power Saving as % Return on Cost of New Pump and Coupling
700	65	$ 2,600	$ 370	$ 200	55
1,400	70	4,920	470	350	74
2,100	73	7,100	600	485	81
2,800	76	9,000	750	590	79
3,500	78	11,000	900	700	76
4,200	79	13,000	1,050	830	79
4,900	79	15,300	1,550	960	62
5,600	79	17,500	1,800	1,100	61
6,300	80	19,400	1,900	1,200	63
7,000	80	21,500	2,050	1,345	65

2. Every deep well turbine should be carefully tested for efficiency prior to pulling the pump for inspection or other purpose.

3. Every deep well turbine installation should be so piped and wired that the water delivered and the energy used can be measured on the individual installation.

4. Every deep well turbine installation should be provided with means of measuring water levels. These measurements should be made at frequent intervals and the data recorded.

5. Whenever the wire-to-water efficiency falls below 60 to 65 per cent it will usually pay to overhaul or replace the pump bowls if the unit is operated any large proportion of the time.

Horizontal Centrifugals

The observations made with respect to deep well turbines apply equally well, although usually with somewhat less force, to horizontal motor-driven centrifugal pumps. Certainly any centrifugal pump, which has been in continuous service for more than ten years and which is being used for "base load," is under suspicion as being uneconomic unless shown otherwise by test.

Table I shows the approximate over-all efficiencies which it is practicable to obtain with modern pumps of this type when operating against a 200-ft. head.

As compared to the above efficiencies four centrifugal units averaging 1.5 mgd. in capacity, which were recently tested in an Illinois water plant, had over-all efficiencies of 55.2, 41.3, 46.5 and 49.7 per cent respectively. The 55.2 per cent efficiency unit was of course the one most used. By installing one complete new unit of high efficiency, at a cost of less than $2,000 for motor and pump, to do most of

the pumping, and by retaining the other inefficient units for reserve, it was possible to reduce the power cost by $600 per year, a 30 per cent return on the investment.

In general it can be stated that any centrifugal pump with a capacity of more than 4 mgd., which is performing with less than 70 per cent over-all efficiency, is uneconomical and should be repaired or replaced if the pump is to remain in continuous service. Complete new pumps and motors in sizes up to 10 mgd. and normal operating heads are available at a cost averaging about $500 per mil-gal. pumped 100 ft. high. A new pump and motor will earn approximately 15 per cent on the investment as compared to an old unit that is 5 per cent less efficient. Assuming that the motor can be used, and only the pump discarded (which is usually practicable), the money expended for the pump alone would produce approximately 50 to 75 per cent return by operating at only 5 per cent better efficiency than the old pump.

In general, any pump in the 1- to 3-mgd. capacity range is uneconomic for regular service if its over-all operating efficiency is less than 60 to 65 per cent or, expressed in another way, if it uses more than 500 kwhr. per mil-gal. pumped 100 ft. high.

Similarly, any pumping unit in the 6- to 10-mgd. capacity range, which is in regular service and which is operating at less than 70 to 75 per cent over-all efficiency, or approximately 475 kwhr. per mil-gal. 100 ft. high, is uneconomic.

The above statements do not mean that all equipment of low efficiency should be replaced. Such equipment is substantially as good as the more efficient equipment if, operated only on peak or fire requirements. Its replacement is justified only when operated enough hours so that the saving in power used exceeds the interest and depreciation on the cost of the new unit. If its use becomes relatively continuous a smaller loss in efficiency will finance the replacement. Expressed in another way, if base-load pumping units of high efficiency are maintained, the less efficient units can usually be economically retained as reserve units for long periods.

Meter Reading

There is a wide range in the costs of meter reading in water works systems. The general average cost of meter reading varies between 5c and 7c per reading. There are many instances where the cost in cities using outside settings is as low as 3c and occasionally one is found where the cost is as high as 13c. A well-operated private plant in a southern city has averaged 1.8c per reading over the last five years. In that plant two meter readers, each with an assistant to remove and replace meter box covers, read 18,500 meters each month—an exceptional performance. The difference seems to lie partly in the amount of gossip the meter reader dispenses and accumulates along the route. The manager of one large operating company advised that the principal difficulty that his company experienced in employing girl meter readers was the time lost through gossiping with the consumers and in negotiating "refreshments" offered to them. He reported that this was eventually corrected by bonus incentives for increased number of readings and decreased errors in reading. Meter reading is essentially "piecework" on which careful route-planning and study can set a standard for each system.

TABLE II

Item	September 1944	September 1945	Totals to September 30 1944	Totals to September 30 1945
Water Revenue				
Residential Metered				
Commercial Metered				
Industrial Metered				
Municipal Metered				
Public Fire Hydrants				
Private Fire Hydrants				
Sprinkler System				
Total Water Revenue				
Water Operating Expense				
Operations				
Source of Supply				
Electric Power Purchased				
Steam Pumping				
Purification				
Total Production Expense				
Transmission and Distribution				
Commercial Expense				
General Expense				
Total Water Operating Expense				
Maintenance Expense				
Pumping				
Purification				
Total Production Maintenance				
Transmission and Distribution Expense				
General				
Total Maintenance Expense				
Total Operating and Maintenance Expense				
Taxes Other Than Income				
Total Water Expense				
Operating Income				
Operating Statistics				
Mil. Gal. Pumped to Mains				
Mil. Gal. Metered				
Mil. Gal. Not Metered				
% Unmetered to Pumpage				
Number of Consumers				

Billing

The handling of billing and collections, assuming an average use of modern accounting equipment, should be done with one employee for each 1,000 bills more or less per month. Some systems handle double this number per employee. In the system cited above for its meter reading performance, a force of seven girls handle the billing and accounting for the 18,500 monthly accounts, an average of 2,650 bills per employee.

Hydrant Repairs

Analysis of the records of a considerable number of cities discloses that the annual expenditure for hydrant repairs will vary from $1.75 to $4.00 per hydrant, with the general average about $2.50. In one city, where there was a nine-year average cost of hydrant maintenance of $8.05 per year per hydrant, investigations showed that the use of hydrant wrenches was substantially unrestricted. Every street employee, fireman, contractor, street flusher and many others had a wrench and used it freely. Further analysis showed that in this city there was an annual replacement equivalent to 70 hydrants for each 10,000 installed, as compared to a general average figure of 25 to 35. Bad practice regarding usage of hydrants adversely affected both the annual maintenance cost and the life of the hydrants.

Meters

The big difference in unaccounted-for water recorded by municipalities is believed to be most largely due to: (1) the character of meter maintenance, and (2) the sizing of meters.

In the normal city, with meters properly proportioned to the service, over 99 per cent of all meters are 1 in. and under. Recently, in a comparatively small, wholly residential town, where an investigation disclosed more than 30 per cent of the pumpage unaccounted for, it was found that the size of meter was determined either by the size of the service or the customer's request. There was no graduated scale in minimum charges. It was found that 2.5 per cent of all meters were larger than 1 in. and that 6 per cent of the meters were 1 in. or larger. Illustrative of the laxity in meter sizing and its effect upon unaccounted-for water is a fountain in the municipal building which continuously runs at a rate of more than 1 gpm. The municipal building was served through a 2-in. meter which failed to register this amount flowing through the fountain and which began to register only when another fixture was opened to nearly full flow. This 2-in. meter was replaced by a 1-in. and in the first month it recorded 30,000 gal. more than the 2-in. meter had been registering.

Investigation further disclosed that there were many 2-in. meters on lawn "gang sprinkler" installations which were rarely used but which allowed the normal household requirements to slip by without registration. One residence even had a 3-in. meter and there were many 1½- and 2-in. meters on residences. It was found that the 1½-in. meters averaged two-thirds more water registration than the 2-in. meters.

Obviously where there are large seasonal requirements there should be two meters —one a small household meter and the other for large requirements—each bearing its proper minimum or service charge.

Meter Registration

It has been ascertained that from 12 to 15 per cent of all water used is at rates of 0.25 gpm. or less. Kuranz[1] found that only about eleven of the 52 cities tested their new meters on a flow as low as 0.25 gpm. Observations made by the author[2] showed that of 221 meters tested in eight different plants, 53 meters selected from service at random failed to register at all when tested at a rate of 100 gpd., and 44 more registered less than 50 per cent of the water passing through them at that rate. In one city in which the unaccounted-for water was 42 per cent, not a single meter of twelve tested registered at 100 gpd. It is the author's opinion that meter testing is scarcely worth doing at all unless the meters are adjusted to catch flows of 0.25 gpm. or less.

Meter Repair Costs

The frequency of meter repairs and the procedure by which meters to be tested are selected vary widely in different cities, presumably reflecting the experience of the various cities and the variations in waters. In the records of ten cities recently studied, an average of 12 per cent of the total number of meters was repaired each year. That would indicate a general average of a meter being thoroughly overhauled once in eight years. The weighted average cost of meter repairs in seven of these cities for which the costs were available was approximately $1.70 per meter based upon approximately 25,000 meters repaired.

In a recent check on a small private water company in which 484 meters were tested, the average over-all cost was $1.26 per meter, divided equally between labor and materials.

Kuranz[1] records figures from approximately 50 plants from which it is computed that the average time for meter repairs in 42 cities was one hour and 24 minutes and the average cost of repair parts 31c. Deducting this 31c from the total for labor and materials of $1.70 above referred to would leave $1.39 as the labor cost. This $1.39 spread over Kuranz' average time of one hour 24 minutes per meter would give a labor rate of $1.00 per hour, indicating a good agreement in the data.

Repairing meters to catch small flows pays dividends. The city accounting for but 58 per cent of its pumpage fifteen years ago (previously referred to) has 30,000 meters. Last year it was paid for 89 per cent of the pumpage—adjusting meters so as to catch small flows was the principal difference. In a single year in another city the meters in one-third the system (about 15,000 total) were tested and adjusted to catch small flows. The results were so impressive that the other two-thirds were then similarly adjusted. That city now gets paid for 90 to 92 per cent of the pumpage. From the above it is concluded that:

1. It is usually practicable to measure and receive payment for 85 per cent or more of the pumpage.
2. The principal factors in reducing "Unaccounted-for water" are believed to be improved meter repair and meter adjustment to catch low flows.
3. Every meter that comes to the shop should be adjusted so as to register accurately all flows at least as low as 0.25 gpm.
4. The average cost of meter repairs is probably between $1.25 and $1.75 per meter. Assuming that as an average 12 per cent of the meters are repaired per year, this is equivalent to from 15c to 25c per year when spread over the total number of meters installed.
5. The total cost of operation and maintenance of more than 500,000 meters in a number of larger cities for which records are available is approximately 50c per meter. This includes routine testing, cleaning and maintenance, as well as repairs.
6. Proper sizing of meters is important. This should be determined solely by the utility.
7. Service or minimum charges should be so graduated as to make over-sizing unattractive to the water consumer.

Car and Truck Operation

There is a wide divergence in the use of cars on various water works systems. It would appear that this use, if properly regulated, should be a reflection of the mileage of mains in the system and the population served.

L. A. Geupel[3] submitted data regarding automobile use in 22 cities with populations varying from 100,000 to 200,000. The average population was approximately 140,000. The average number of cars and trucks in these systems was 27 per system or a weighted average ratio of one car per 5,300 population. The average miles operated per year per 1,000 population was 1,870.

An analysis made in the author's office of fifteen cities varying in population from 225,000 to 1,000,000 showed a weighted average of 8,000 population per car and an average mileage of 1,120 per year per 1,000 population. In one city which was investigated in detail, there were substantially no restrictions on the use of cars and all cars were stored in the private garages of the men using them. In this city there was an average of one car for each 4,500 people and the average mileage per 1,000 population was 2,860; the annual mileage per mile of main was 1,310, a figure two and one-half times the general average; the average annual cost per mile of main was $83.50, as compared to a general average of $28.20; and the annual cost per capita was 18c, as compared to a general average of 6c.

In general it is believed that a reasonable mileage for cars and trucks in a water works system is best indicated by the mileage of mains which they are called on to service and a general figure of 500 miles of travel per year per mile of mains in the distribution system is reasonable of attainment.

Distribution System Operation And Maintenance

This item, excluding services and meters, is primarily a reflection of the mileage of mains in the system and the size of the mains, although if there is a large amount of material other than cast iron it may also be affected thereby. In general, the cost of distribution, system operation and maintenance, exclusive of services and meters, in well-maintained systems averages about $12 per inch diameter per mile of pipe per year.

Operating Records

Every water utility should have a standard form of report. This report should be prepared monthly so as to show current costs and efficiency in comparison with those of the corresponding month of the previous year. The annual report does not serve this purpose adequately. The post mortem review of operations, too long dead, which it records, simply embalms inefficiency, the correction of which requires prompt knowledge of its existence.

An example of what is believed to be a minimum in monthly reports is shown in Table II. This is usually expanded to show details.

Municipal utilities would benefit, as those privately owned have benefited, from the adoption of the Standard Classification of Accounts prescribed by the National Association of Railway and Utility Commissioners.

Conclusions

The foregoing illustrates some of the checks which can be readily applied to the ordinary water works operations. It is hoped that those who read this discussion will be moved to analyze their own operations, compare them with these very general standards, and establish "par" for each operation in their own plants.

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LEGAL RESPONSIBILITIES OF WATER OPERATORS

By JOHN H. MURDOCH, Jr., Attorney
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A WATER works operator has the legal responsibility to install, maintain and operate reasonably adequate and safe facilities and to render reasonably adequate service and to deliver to the public reasonably pure water.

That statement may cover the situation but probably a little more detail would be helpful.

A water works operator has the legal responsibility to obey specific mandatory laws and the lawful orders of the constituted health authorities. It is assumed that you know the laws applicable to your work and that as law abiding citizens you obey laws and lawful orders. A fuller statement of your legal responsibilities is needed.

While such a fuller statement is needed, some limits as to subject matter must be placed.

There have been deliberately eliminated from this paper any matters as to which the legal responsibilities assumed by a water works operator differ because the water plant is owned by a municipality, an authority or a private company. In the matters to be covered here the same principles are applicable *no matter what the type of ownership.* For that reason the phrase "water utility" is used to designate the owner of the plant whether that owner be a municipality, an authority or a private company.

A water utility acts through its individual operators, and when those operators fail in the performance of a duty or responsibility to others, then the water utility has failed. And if damage is caused, then the water utility is liable for money damages. Some types of such failures to perform legal responsibilities are to be considered.

Definitions of Some Terms

To avoid the necessity of long repetitions in this discussion, some definitions are needed. These definitions and the discussion which follow them are not intended to be legally accurate, complete and exhaustive. To make them such would be exhausting and, practical-wise, unnecessary. Besides, this is not a legal treatise on Torts but a short talk among friends. Now for some definitions.

Negligence: "The failure to observe, for the protection of the interests of another person, that degree of care, precaution, and vigilance which the circumstances justly demand, whereby such other person suffers injury." (Cooley on Torts.) Negligence is also defined as "Any conduct which falls below the standard established by law for the protection of others against unreasonable risk of harm."

Standard of Conduct Established by Law: The standard of conduct to which one must conform to avoid being negligent is that of a reasonable man under like circumstances.

Reasonable Man: Reasonable man is a person exercising those qualities of attention, knowledge, intelligence, and judgment which society requires of its members for the protection of their own interests and the interests of others.

Unreasonable Risk: A risk which outweighs the value attached to the conduct which involves it. Illustration: A high pressure pipe line in a busy street may burst and cause damage. To operate such a pipe line, therefore, involves a risk. Its social value outweighs this risk and the placing of it is not conduct involving an *unreasonable risk.* On the other hand, allowing unchlorinated water to be distributed while repairing a chlorinator or because of a depleted supply of chlorine would be conduct involving unreasonable risk.

Negligent Conduct: May be either

(a) An act which the actor as a reasonable man should realize involves an unreasonable risk of causing an invasion of an interest of another, or

(b) A failure to do an act which is necessary for the protection or assistance of another and which the actor is under a duty to do.

Having gone a long way around the hill, let us look for a short cut. When, on principle, is a water works operator negligent? From the defintions this conclusion can be stated: A water works operator is negligent when his conduct brings an unreasonable risk of harm to his consumers or to persons or to property of others; and, when his conduct is not up to that standard of conduct, recognized by water works operators generally as required under like circumstances, to protect from unreasonable risk others to whom a duty is owed. Each operator is judged by a standard established by good practice. And standards of good practice are established by the consensus of opinion of such groups as this Association and others with similar objectives.

Some Legal Principles

Before there is a legal liability for damages in negligence cases certain elements must be present. A statement of these elements is needed.

First: Damages must have been suffered by some person.

Second: This other person must be one to whom the actor owes a duty of protection or assistance.

Third: The actor must have done or failed to do some act.

Fourth: This action or failure to act must have caused the damage.

Fifth: The action or failure to act must have involved an *unreasonable* risk to others.

Sixth: The action or failure to act must not have measured up to the standard of good practice under the circumstances.

Seventh: The failure to act must have been a failure to act in a way in which the actor was under a duty to do.

In short, before there is a legal liability for damages for negligence there must be negligent conduct resulting in damage to a third person to whom a duty is owed.

Examples of Application of Legal Principles

With this background of definitions and legal principles, consideration will be given to three classes of cases in water works operation in which the principles are applied.

Damage Caused by Water Escaping from Mains

One of the frequent, but usually informal complaints against a water utility is that a leaking or broken main floods and damages property. Claims based on such occurrences are not usually covered by public liability insurance, and if the utility is liable the damages collected are often considerable. For these reasons this class of damage will be touched upon briefly.

As was pointed out above, the maintenance and operation of a high pressure water main in a busy public street does involve the risk that water may leak from such main and cause damage to the property, or the persons of innocent people. However, since no other way has yet been found to get water to the places where it is needed in our cities, and since the water is needed at those places for the uses of industry, commerce, domestic life, and fire service, the social value of the service far outweighs the risk involved and the risk is therefore reasonable. That being true, the mere placing and operation of the main is not negligence. The water utility is not an insurer that its mains will not break or leak. *It is not liable for damages merely because water has escaped and caused the damage.* Negligence must be proved.

There have been cases, however, when liability has been imposed and damages paid. One important city paid a large claim when these facts were proved: The main was laid in a ditch below which there was a large sewer; the main was partly supported by timbers which were old and weakened when first installed under the main; known to the water works operators, many subcellars were below the level of the main and sewer; the ditch was opened several times to repair leaks caused by the sinking of the timbers and main; a large section finally broke; and water flooded adjacent cellars. Here we have a perfect example of negligence.

There was damage; the utility owed the duty to the person damaged of so installing and operating its main that no more than a reasonable risk would be involved; the operators of the water utility did not support their main; this failure of support caused the damage; the failure to properly support the main was failure to do what a reasonable man would have done under the circum-

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stances. The conduct of the water works operator did not measure up to the standard of good conduct recognized by water works operators generally.

In another city a change in operating conditions as to pressure brought about a pipe line failure and a flooding of property. The line was designed for fifty pounds pressure and light class pipe had been installed. Many years later the system was rearranged and a pressure of one hundred and fifty pounds was put on the line. The line burst and damage was caused. There was negligence here because the act of placing that added pressure on a pipe line not designed to carry it was an act not up to the standard recognized by water works operators generally.

In another case a new line was laid. The street paving above the line kept sinking and at a lower level a "spring" developed. This condition continued for two years without an inspection of its main by the water utility. A major leak eventually developed and resulted in a flooding of cellars. The failure to inspect after the suspicious conditions developed was held to be negligent, as not being up to standard practice under the circumstances. Water works operators have long known the significance of "springs," which suddenly develop along a pipe line, as a suspicious condition which should not be neglected. It pays to locate and stop leaks.

Again, a known and serious leak was left unchecked for a period of twelve hours, during which no attempt was made to check it by closing valves or otherwise, and the flow of water increased due to the worsening of the blow out. The neglect in failing to attempt to stop the flow for a period of twelve hours, after discovery by the water utility, was deemed to be negligence.

It seems, therefore, that the mere fact of water damage from a leaking main is not enough to impose liability but that such liability is imposed when the water works operator has failed in the legal obligation to use the care and skill recognized as standard among operators generally, and when that failure caused injury and damage.

Water-Borne Disease

Ever since it became known that clear, cool, sparkling water, free of objectionable tastes and odors might yet be deadly as a carrier of typhoid and other water borne diseases, every water works operator has had the dread that some day, somehow, an epidemic would strike in his community for which his water utility would be found responsible. It may seem a contradiction in terms, but this very constant dread has been health-giving to ourselves and to our consumers. The dread has brought with it realization of great responsibility and a determination not to be found wanting. Our operators, our chemists, our bacteriologists, our engineers and our utility officers have all devoted their talents to the guarding of our public water supplies against disease. The State and Federal Health Departments have been efficient, resourceful, firm and untiring in the work. Its district engineers have been preaching the gospel of cleanliness, efficiency and constant care in every city and cross roads of our state. To all must go credit for the splendid progress that has been made in the last forty years. The battle has been won but the advanced position must be held by constant attention to duty. We have a call to continued service.

A water works operator has the legal obligation to so operate his facilities that neither through his act nor through his neglect of a duty, lawfully imposed, will water borne disease bacteria reach his consumers. That is *his* obligation.

The water utility is not a guarantor of the quality of the water furnished and by selling it or by rendering water service it does not give an implied warranty that the water is free of harmful bacteria. The reason for this rule seems to be that the volume handled, its sources, the possibilities of contamination by persons or agencies over which the water utility has no control, all combine to make it unwise and unjust to require the utility to guarantee the water. The rendering of water service in great quantities does involve some risk but the risk is reasonable when weighed against the large social advantage of having water delivered by an organization which assumes the obligation of seeing to it that its operators measure up to the standards of such groups as this Association.

However, the water utility is liable for damages caused by negligence of its operators, and such liability has been imposed. Consider some instances.

Occasionally an ill advised operator thinks a little bad water will do no harm and be unnoticed when, due to a break down, no other water is available. The sequel is usually a very sad story.

For twelve hours water was taken through an emergency intake from a highly polluted river. The normal source could not be used because of a break in a line. Deaths followed which were proved to have been caused by drinking water brought into the system from the river. Here was action below the standard and, therefore, negligent.

A chlorine machine broke down and water from a polluted source but clear, cool and sparkling, was, with the full knowledge of the water works operator, fed into the system. Deaths followed, and those deaths were caused by negligence. An operator failed to meet his legal obligations.

In other cases the water works operator used facilities in normal operation which were known to be faulty and in condition to permit pollution of otherwise good water.

In one city a splendid filtration and chlorination plant was in operation. Water from it was taken under very low head some distance through a buried conduit. The conduit was in ground subject to flooding by contaminated water and the conduit was known by the water works operators to have holes through its walls. By the standard of reasonable men in water works operation the conduct of these operators was below par. Negligence resulted in epidemic.

In another case the water works operators of a utility knew that the casing of a water well was bad and that impurities might reach the water through such defective casing. They continued the well in use and were negligent.

Water Safe at Source, Contaminated in Distribution System

The cases which have been brought forward up to this point were cases in which the water works operator failed to live up to his legal obligations in using reasonable care in putting water into the distribution system of the water utility. Under such conditions, the other essentials being proved, the utility would be liable for damages. There are a number of old cases and some new ones where the contamination came into the distribution system after the water left the source. There are some interesting variations of principle in these cases, and further possible variations which deserve thought. The illustrations which follow are in part imaginary but could happen.

A city has two systems for water service. One is high pressure, non-potable, for fire service. The other is high quality potable water. To operate drawbridges in the city and to guard against delays due to possible failure of one system both systems are connected to water driven pistons operating the drawbridges. A valve at each piston was supposed to keep the fire service water out of the lower pressure potable system. Some water works operator forgot to install one of these valves. Many complaints of bad water came from the district near the bridge where the valve was missing. These complaints were heard but unheeded for months until an epidemic developed and pollution of the supply was proved. Here there was negligence on the part of the operator who failed to install the valve; negligence on the part of the operator who conceived of the idea in the first place; and gross negligence on the part of the water works operators who failed to make any investigation as to the cause of the bad water in the neighborhood. None of them lived up to the standard.

Again a case of two systems, one potable and the other high pressure non-potable fire service. Here a cross connection had been ordered removed, but, instead the connecting valve had been merely closed. This cross connection valve was opened by mistake and bad water was let into the potable supply system. After unexplained conditions indicated that something was wrong nothing was done to warn consumers for a number of hours. An epidemic developed. There was negligence in failing to remove the cross connections when ordered, there was negligence in opening the old cross connection, there was negligence in failing to warn consumers when the suspicious conditions developed.

In another case the water utility has knowledge of the existence of a cross connection within a mill or factory. The cross connection is installed by and for the convenience of the mill company. Under orders of the health authorities it is so valved as to normally prevent water passing from the mill supply to the water utility system. All goes well until some person in the employ of the mill by-passes the properly valved by-pass and contaminated water reaches the system of the utility.

Has any water works operator failed to perform a legal obligation in such a case? Consider several matters in this connection. The cross connection was solely for the benefit of the mill and was on mill property and was installed and controlled by the mill. The water utility had no legal control over it. It was installed with the knowledge of the public health authorities and in accordance with their requirements. The cross connection was opened by one over whom the water utility had no control. If there is nothing more to the case than this it would be very difficult to prove negligence on the part of any water works operator.

If, however, it develops that the cross connection has been open for several months and has during all that time been putting polluted water into the system, and if it further develops that during all that period the water works operator failed to collect sys-

tem samples in the district where the supposedly closed cross connection was known to be, and examine them for evidence of contamination, then I think it possible that there was negligence. It is probable that a reasonable man, a good water works operator, would think he had a legal obligation to police his own distribution system in the neighborhood on the off chance that some mill hand might open the by-pass and cause serious damage.

The legal obligation would probably be different if the existence of the cross connection were absolutely unknown to the water works operator. In such a case there would be little, if any, reason to think that system samples should be collected in that particular section. Water works practice probably indicates that, as a reasonable man, a good operator should collect system samples more frequently in regions where known conditions indicate potential dangers, but only representative samples where no known danger spots exist.

Unjustifiable Obligations Recently Expected

This matter is mentioned because of a tendency on the part of public health authorities in some states (not Pennsylvania) to attempt to impose on water utilities what appear to be unjustifiable obligations. These authorities, knowing that cross connections are hazards, even though sealed and valved, and knowing that faulty domestic plumbing may cause localized contamination through back-siphonage, and knowing that some consumers have private well supplies of doubtful quality, are seeking to impose on water works operators the obligation of policing the premises and of inspecting the plumbing of all of the consumers attached to the lines of the water utility.

Such an obligation ought not to be assumed. The water utility probably has no legal right to make the inspection and it certainly has neither the money nor the ability required to make the original exhaustive and complete surveys, thereafter, periodic inspection at frequent intervals, which alone could give real protection. By once assuming such an unjust obligation the water works operator may possibly find one day that he is being held negligent in failing to do thoroughly that which he had unwisely undertaken to do. Good water works practice certainly indicates that it is better to do well that which water works operators have the legal obligation to do—police their own systems and facilities—than to raise a false sense of security by half doing that which they have no legal obligation to do.

FUME TRAP FOR DIESEL AND OTHER INTERNAL COMBUSTION ENGINES

By DON C. CALDERWOOD

Engineer, Pennichuck Water Works Co., Nashua, N. H.

IN THE engine rooms which house Diesel engines there is usually a problem of fumes, in some cases to such an extent that even with all the windows open these fumes cause smarting of the eyes and throat irritation. These fumes, for the most part, originate in the crankcase of the engine and usually find their way into the engine room through the crankcase breather pipe. This problem is particularly acute in installations which have worn or stuck piston rings because the highly compressed vapors in the cylinders blow by the rings, producing a back pressure in the crankcase. This back pressure, in turn, forces the oil vapor and fumes out through the breather pipe.

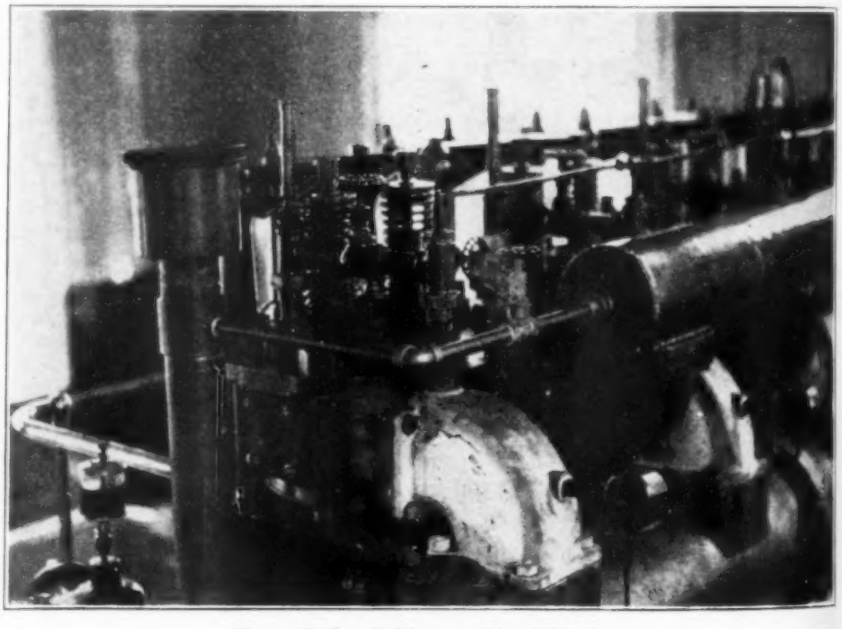
All this trouble can be eliminated by a simple piping job. Drill and tap both the air-intake manifold and the breather pipe for ½ inch pipe. In many installations it makes a much easier and better looking connection if the breather pipe is extended so that both connections can be made at the same level. Connect with a ½ inch pipe, putting a gate valve in the line, as shown in the accompanying picture.

After making the piping changes, start the engine, first *making sure that the ½ inch valve in the new connection is closed.* When the engine is well warmed up, open the gate valve slowly until the suction obtained through the connection to the intake manifold overcomes the back pressure in the crankcase. A simple way to determine when this pressure is equalized is to blow smoke by the end of the breather pipe; if the smoke is slowly forced away from the end of the breather pipe, open the valve a little more; if the smoke is drawn into the breather pipe more than can hardly be detected, close the valve a little more. It usually takes a little patience to obtain just the right opening of the valve, so when this is obtained, tighten the packing nut on the valve with a wrench so that the vibration of the engine will not change the correct adjustment.

Caution—Considerable care should be taken in adjusting this valve opening, making doubly sure that it is not open too wide. If this valve is open more than necessary, the lubricating oil vapors in the crankcase will be drawn into the cylinders and burned as fuel; this in turn will cause high lubricating oil consumption.

With this connection you are not only freed from the fumes which formerly gave you much discomfort, but you are actually burning and obtaining power from them, but remember that as a fuel, fuel oil is always cheaper than lubricating oil, so watch the valve setting for economy sake.

This type of connection is not confined to Diesels alone since it can be used on any internal combustion engine.



Fume Take-off Line on Diesel Engine.
Suction on Crank-Case Breather Pipe from Intake Manifold Is Adjusted by Setting of Valve in the One-Half Inch Line.

DRILLING AND DEVELOPING DEEP WELLS

By J. ARTHUR CARR

Superintendent of Water, Ridgewood, N. J.

The author of this article has for several years served as co-chairman with Jas. A. Harding of the A. W. W. A. Committee on Deep Wells and Deep Well Pumping.

WHILE some of the ideas expressed in this article are applicable to wells of all types, they are offered chiefly from experiences in the construction of wells in the red sandstone formation, such as is encountered in Northern New Jersey.

In the writer's opinion, the most important points in the construction of a new well are:

1. Full and complete specifications and a bid sheet permitting a fair comparison of prices.
2. The selection of a qualified contractor.
3. A full-size hole that is plumb.
4. Proper sealing.
5. Proper and complete testing.

(1) Specifications and Bid Sheet

The preparation of specifications is not as simple a matter as it may appear if the interests of both the purchaser and contractor are to be safeguarded. There are several points both in the specifications and bid sheet which, unless they are carefully covered, may cause difficulty in deciding the low bidder and create misunderstanding in making payments.

Usually the most expensive portion of the well is the portion which is cased down from the surface and into rock. Frequently the depth into rock to which the casing will be carried cannot be determined in advance. In order that all bids may be considered on a comparable basis, it is recommended that a statement be made in the specifications similar to the following: "For the purpose of comparing bids, the distance from ground surface to rock will be considered to be .. feet," the distance mentioned being the approximate depth the rock is believed to be.

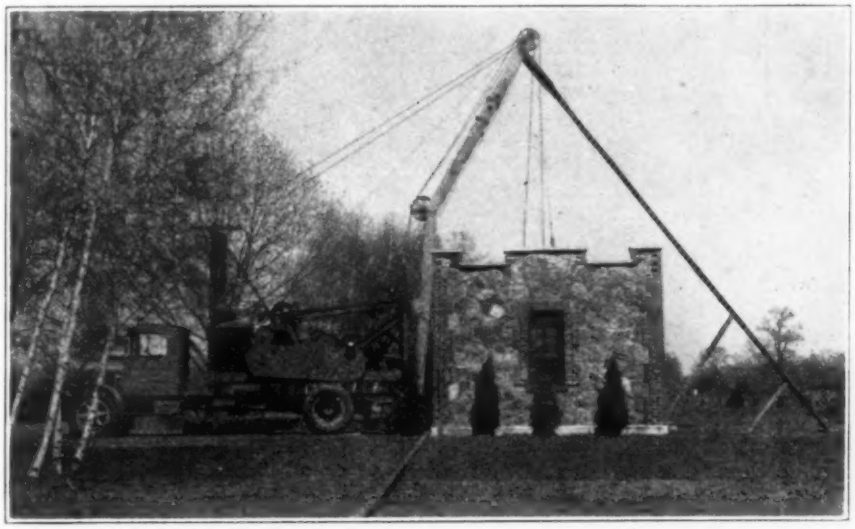
The depth to which a well is to be drilled is also frequently difficult to state beforehand. So that bids may be comparable, a statement such as follows is advisable: "While the contractor's bid is based upon a maximum depth of .. feet, it is understood that drilling may be stopped at any depth by the engineer; however, it is guaranteed that the contractor shall be paid for at least .. feet of drilled well."

The cost of at least one test should be included in the bid price. In addition, the specifications should stipulate the amount to be paid for any additional testing which may be required. This amount is usually set up on an hourly basis.

(2) Selection of Drilling Contractor

Next in importance, after bids are properly filed and evaluated, is the selection of a skilled and experienced contractor. The contractor selected should be one who is not only financially responsible, but more important, one who knows how and has the equipment to do a first class job and also the desire to do it. In this connection, a method which embraces the prequalification of bidders is desirable.

Full and accurate records are most essential for the proper future operations of a well. There should be absolute insistence that the contractor keep and turn over to the owner detailed information as to what is being done and what is happening as the work progresses. Samples of drillings at various depths should be preserved and the location of any change in formation noted.



Deep Rock Well Development, May, 1942, Ridgewood, N. J.

Here is seen the machine developed to work over the tops of existing well houses. This development work on these rock wells improved yields from 50 to 200 per cent—something heretofore not considered possible.

(3) A Plumb and Full Sized Hole

It is poor economy to drill holes that are likely to later prove too small. The hole should be started of sufficient size to permit as many reductions in diameter as may be necessary and still have ample diameter for the installation of a pump of high efficiency.

During construction, a well should be plumbed and gauged at frequent intervals in order that the purchaser may be assured a straight and plumb hole of full required diameter. Watching the cable to see that it hangs in the center of the hole is a rough check for plumbness. Bit diameters should also be frequently checked.

While a hole that is straight, although slightly out of plumb, does not interfere to any great extent with a pump setting, a

zigzag or corkscrew hole, or one with flat spots or constrictions in diameter, may cause much trouble and expense.

(4) Proper Well Sealing

In the writer's opinion, there is only one sure and permanent method of sealing a rock well to shut off surface or top ground water, and that is by double-casing and cement filling the annular space between the two casings. The inner casing may be installed either before or after completion of drilling and should extend well past all soft or broken formation near the surface of the rock. If the inner casing is placed before the completion of drilling, care should be taken to avoid jarring and cracking the cement during subsequent drilling operations.

Considerable care should also be exercised in placing the cement to avoid bridging and to entirely fill the space between

View of the Top of the Double Packer Used in the Surge Treatment.

casings. In placing the cement, the method most frequently used is to pipe the cement slurry all the way to the bottom of the space to be grouted. Grout should always be applied as one continuous operation.

(5) Testing

Tests should be made with a pump of sufficient capacity to handle more water than it is expected the well will produce and with the pump set at a lower level than the maximum anticipated draw down. This should be done so that the maximum yield and the yield at different draw down levels may be determined.

Opinions as to the duration of tests vary. The writer favors 72 hour tests of continuous pumping, especially in new well fields or where there is a possibility of interference with other wells. For 60 hours the well is pumped at maximum capacity and draw down. Usually after the first 24 hours a point is found where the well stabilizes and the level does not change. The well is then pumped at that level until the 60th hour. The pumping rate is then gradually reduced at intervals of about 1 hour and the draw down at different capacities noted. By this method a good record of the capacity of the well at different drawn down levels is obtained. From this data the most economical pumping level may be selected—a matter of considerable importance when considering the day-after-day costs of operation.

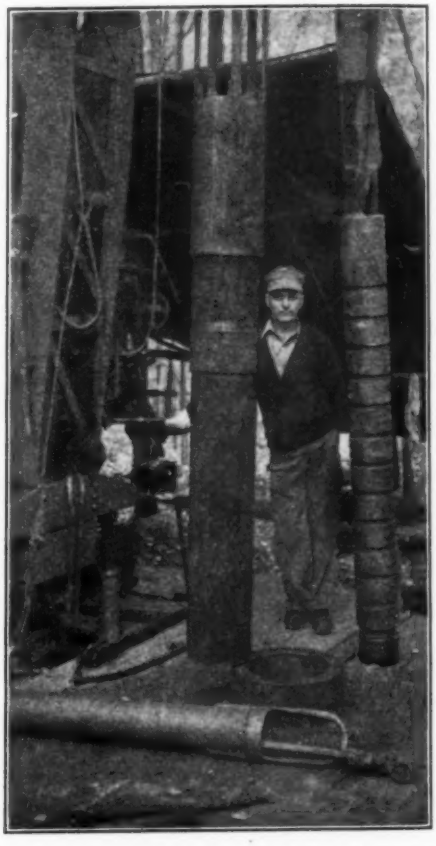
Some Notes on Developments

In the paragraph relative to plumbness and size, mention was made of development. In the past it has generally been accepted that when the drilling of a rock hole is completed, nothing further can be done to increase the yield. From his experiences in Ridgewood the writer is convinced that the odds in favor of increasing the yield in rock wells can be bettered by application of some of the methods of development heretofore used only in the development of sand and gravel wells.

During 1940 two Ridgewood wells were developed, using the conventional valve type surge plunger such as is used in sand wells. The capacity of one well was increased 30 per cent and that of the other well 200 per cent.

In the course of agitation of those wells, many cubic feet of sand, clay and pieces of rock were brought into the well. Along with the other material were many small pieces of cement which seemed to indicate that practically all of the action due to agitation was taking place immediately below the casing. This seemed to indicate that better results would be obtained if the effects of agitation could be spread over the entire well wall.

With that thought in mind, a steel cage-like structure 30 feet long with a temporary seal at top and bottom was constructed. This device was then suspended on a string of pipe and lowered to the bottom of the next well constructed. The well was then developed for several days, using a long, heavy, steel plunger



Lower Section of the Double Packer and the Agitator Used.

in place of the conventional one. The packers were raised at varying intervals of time until the well wall had been exposed to agitation for its full depth. This method of development was used on four wells during 1941 and the capacity of all was increased, the amount of increase ranging from 50 to 200 per cent.

Early in 1942 development was applied to a well built in 1932. This well was producing 80 GPM at a pumping level of 120 feet. After development the well is producing 170 GPM at the same level.

TREATING INCRUSTED WELLS

Effective Means of Increasing Production at Critical Periods

By JOHN R. GOETZ and F. L. COVENTRY

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Water Department, Mattoon, Illinois

SOMEONE has very aptly explained corrosion as the process of the return of a metal to the composition in which it is found in nature—in other words, a return to nature through natural processes. For example iron ore and rust are one and the same chemically.

Incrustation is, on the other hand, a deposition of material. Incrustation with which this paper deals results in the clogging or stoppage of well screens and/or water bearing formations. It is the result of deposition or collection of material in and about the openings of the well screen and the voids of the water bearing sands or gravel. It is usually hard and cement like; but it may be soft and gummy. Where the water is of an depositing nature, incrustation will appear sooner or later, and it is of importance to give careful consideration to all methods for the prevention or retarding of incrustation.

Naturally such choking deposits cause a marked decrease in well yields and something must be done about it.

Well Treatments to Boost Yield

In general, there are two successful methods for treating incrusted wells, namely, (1) pulling the incrusted screens, treating them for the removal of the incrusting material and resetting them; (2) treating the screens in place without pulling them.

It is obvious that the first method is effective but it involves considerable risk and labor. If the incrustation is very hard it sometimes requires immense power to withdraw the screen, occasionally resulting in breaking the pulling pipe, or damaging the screen. There is also some risk involved in replacing the screen after treatment. Treating the screens without pulling them with acid is not a new discovery so far as the use of the acid is concerned, yet we found very little information and less experience by water works operators in the use of the method.

Our treatment of a well involves the use of muriatic acid (hydrochloric acid of commerce) which can be purchcased in convenient containers or carboys, usually of 12 gallons capacity. Full strength acid should be used and at least enough to fill the screen. As shown in the illustrations a length of garden hose about ¾ or 1 inch in diameter, and of sufficient length to extend to the *bottom* of the well, should be obtained. Provision should be made for wiring the hose in place as to depth in the well. The hose is lowered until it is within a foot or so of the bottom of the screen. If the screen is more than three or four feet long it is well to add enough acid to fill one foot of screen, then lift the hose one foot and add more acid. (Note—in the picture, you may see the rule and the wire which is fastened to the hose down in the well.) Into the upper end of the garden hose is taped (tire or friction tape) a length of small rubber tubing. The other end is connected to the carboy by means of a glass tee. A rubber syringe bulb is also attached to the tee to enable the operator to prime the acid "syphon." The amount of acid for each foot of screen is calculated ahead of time, and can be checked by the rule as the level drops in the carboy. Example: A 10-inch screen will require about four gallons per foot, or one-third of the height of a 12-gal. carboy.

The hose end is lowered to the *bottom* and worked upwards in order to produce as little dilution of the acid as possible. The acid being heavier than the water, will displace the latter, but it mixes with water so readily that it is easily diluted.

The acid charge is permitted to stay in contact with the screen for twelve hours, during which time the drop pipe and pump may again be installed ready for operation. Since we have a lime-soda softening plant we merely start the well pump and allow the operation of the plant to compensate for any excessive acidity in the first water coming from the well.

Our experience has shown that as much as a 40% increase in well production followed the acid treatment of the well.

A Few Precautions

Necessary conditions for acid treatment of wells are:

1. The well screen must be constructed of metal which will not be damaged by acid. Brass or bronze screens require muriatic acid, while iron requires nitric acid.

2. The screen must be constructed of one metal to avoid establishing rapid galvanic corrosion which would greatly damage the screen.

3. There should be some definite knowledge of the kind of incrusting material so as to determine the proper acid. Samples of incrustation taken from other wells in the locality are usually available. In the absence of such samples an analysis of the water will usually indicate the proper procedure.

Well Treatment Set Up

The drop pipe is up and swung to one side out of the way. The rubber hose is down in the well, the lower end resting on the bottom, and the first charge of acid is applied. The hose is hung from the wire seen by the rule, and is drawn up a foot at a time during the emptying of the carboy sufficiently to completely fill the screen. The drop pipe is returned to the well and twelve hours or so later the well is pumped free of residual acid and returned to service. Note the carboy tubing arrangement, and the bulb for starting the acid syphoning itno the dosing drop hose.

BASIC FACTORS IN THE POLLUTION OF SUB-SURFACE WATER

By L. C. MacMURRAY

Assistant Sanitary Engineer Maryland State Department of Health, Baltimore, Maryland

THE problems involved in the pollution of sub-surface water frequently present many difficulties to the field worker engaged in the estimation of the effect of a focus of pollution on a water supply derived from underground sources. Much confusion exists due to too general acceptance of certain pseudo-scientific myths relating to the flow of sub-surface waters and the capacity of soils for ridding those waters of pollutants. The justification for this discussion lies in a desire to abate some of the misunderstanding of the subject by presenting certain of the fundamental physical and biographical principles involved, together with a few elementary concepts of ground water hydrology; and to underline the conclusions reached with the results of specific experimentation.

Mountin[1] calls attention to the low position accorded the routine sanitation activities of health departments, ascribing it, in part, to the lack of application of the biological principles upon which sanitation should be based. This observation might well have been extended to include not only biological but physical principles. Thus ground water pollution is limited not only by the environmental conditions affecting bacterial metabolism but also by the physical laws governing the movement of water through capillary channels. In amplification, the slope of the time-concentration curve is influenced by temperature, moisture, pH and food supply, while the movement of ground water is influenced by the permeability of the soil and the slope of the hydraulic gradient. An understanding of these and other basic principles is essential to the successful interpretation of field observations and analytical data collected in relation to a specific problem.

Basic Concepts and Terminology

Water precipitated in the form of rain or snow either runs off the ground surface into streams or lakes, becoming surface water, or enters the ground to become sub-surface water. That portion entering the ground is affected by a variety of physical forces. Its downward travel is impelled by the force of gravity, modified by the permeability and absorption characteristics of the soil and withdrawals by vegetation at the surface. If the force of gravity controls the movement, the water passes downward until it reaches an impervious stratum through which it can not pass. The impervious stratum may be clay, compacted and cemented sandstone or metamorphic and igneous rocks underlying the loose, uncompacted surface deposits. Through such a stratum there is either no vertical movement of water or the movement is so imperceptible as to be negligible. The downward travel of the water is halted by this barrier and the continued arrival of increments of water results in the filling of the interstices between the individual grains and saturation of the overlying material. The extent of this saturation is dependent upon the amount of precipitation and the discharge of water from this zone of saturation[2] through springs, lakes and rivers, so that complete saturation of the soil between the ground surface and the underlying impervious stratum seldom occurs. The upper surface of the zone of saturation is called the water table. Above it exists a zone of under-saturation or aeration where the interstices are only partially filled with water. However, all of the water entering the zone of aeration from the surface does not pass through it into the zone of saturation, since some is retained by surface forces of attraction at the boundaries between the solid material and the particles of water. Furthermore, immediately above the water table some water is held against the force of gravity by capillarity in a "capillary fringe." Figure I shows the relative positions of these various zones.

Within the zone of saturation, the movement of the water is still influenced by gravity but it is further modified by the slope of the underlying impervious stratum. The movement in general will be influenced by the slope of the inclined surface of the impervious stratum and toward a point of ultimate discharge such as a spring or stream bed where the water table intersects the ground surface. The difference in elevation between the maximum elevation of the water table and the point of discharge will establish an hydraulic gradient similar to that established by a pipe or other conduit. If at some distant point the moving ground water passes under an impervious stratum, a pressure may be built up within the confined water resulting in artesian flows when the waterbearing stratum is tapped by wells.

In addition to the slope of the hydraulic gradient, percolation, or the rate of movement of ground water, is dependent on the permeability of the soil or the rate at which water will pass through it. This, in turn, is influenced by the porosity of the soil, i. e., its property of containing interstices. The diameter, arrangement and interconnection of these interstices have an important bearing on the permeability of the soil. In heterogeneous material the finest interstitial material which occurs in sufficient amounts to surround the grains of coarser material controls the rate of percolation.[3]

The specific rates of percolation for many materials have been measured. Tolman[3] presents the following average field velocities in feet per day in natural granular materials:

Type of Material	Grain Size in mm.	Average field velocities in feet per day when the hydraulic gradient is: 1%	100%
Silt, fine sand, loess.....	0.005— 0.25	0.065	6.5
Sandstone, medium sand....	0.25 — 0 50	1.16	116.0
Coarse sand, sandy gravel..	0.50 — 2.0	6.33	633.0
Gravel	2.0 —10.0	30 0	3,000.0

Tolman also directs attention to the fact that normal ground water gradients seldom exceed one per cent.

The rates of percolation given above are below the critical velocities separating turbulent flow from laminar flow. We may predict from this that in ground water flow there is no fluctuation in the position of individual particles of water from the top to the bottom of the water-bearing stratum, but rather that each particle tends to move in relation to other particles according to their relative specific gravities and the hydrostatic pressure exerted on each.

With these elementary concepts of sub-surface hydrology in mind, we are now in a position to investigate certain biological principles relating to the metabolic activity of bacteria under unfavorable environmental conditions.

History and Survival of Bacteria

The primary danger involved in the drinking of water either from surface or sub-surface sources arises from the possibility of contracting a disease following the ingestion of certain pathogenic bacteria. These include members of the genera *Salmonella* (Salmonella paratyphi), *Eberthella* (Eberthella typhosa) and *Shigella* (Shigella dysenteriae), which bear a close relationship to the genus Escherichia, whose normal habitat is the intestines of mammals. These latter, Escherichia, constitute a portion of that group, which with members of the genus Aerobacter, was formerly referred to as the "B. coli" or "coli-aerogenes" group, and more recently the "coliform group."

It obtains that if the normal habitat of these organisms is the intestines of mammals and one mode of transmission of the specific diseases is by drinking water, then conditions must be such that the organisms enter the water, are carried to a point where the water is withdrawn for domestic consumption and survive in sufficient numbers to produce a clinically recognizable manifestation of the disease. The accepted procedure among sanitarians is to utilize coliform organisms which are normally present in all fecal discharges as indices of pollution rather than specific pathogenic bacteria which would be absent except in the case of illness amongst those contributing to the source of pollution. The expectancy is that if typhoid or dysentery patients or carriers contribute excreta to a focus of pollution, this specific pathogenic organism will pass through the same channels as the coliform organisms discharged by well persons and thus affect the water supply. Fortunately, the culture of the coliform bacteria presents less technical difficulties than the culture of the related pathogens. If a slight error exists in this hypothesis, it is that the pathogens are usually somewhat less resistant in an unfavorable environment than the coliform organisms, and hence the application of the hypothesis in practice generally results in increased safety.

Continuity of a favorable environment plays an important role in the viability of all bacteria and in particular those which are non-sporing, as are all members of these groups. Thus, changes in temperatures, pH, moisture, food supply and other environmental factors have a marked effect upon the bacteria, and when the changes are severe, induce rapid death. However, the time-concentration curve follows a modified logarithmic curve so that

even after a relatively long period of time the more resistant individuals survive. The contrast between conditions surrounding life in the intestinal tract where there exists a constant temperature and pH and an abundance of food and those outside of the intestinal tract at substantially lowered temperature, altered pH and a scarcity of food serves to rapidly diminish the number of organisms. Obviously, if the time interval between the source of pollution and the use of the water is sufficiently long, the chance for survival of any individuals is almost negligible. Therefore, aside from other factors, a lengthening of the time interval adversely affects the opportunities for survival of the organisms.

In addition to these environmental factors related to their own metabolism, the bacteria must overcome a number of natural physical obstacles. These obstacles include the natural retention of bacteria in the soil by filtration, resulting from absorption and sedimentation; clogging of the interstices between the grains as filtration proceeds; and the rise and fall of the ground water.

It may be said, further, that many of the conditions surrounding groundwater flow influence the travel of bacterial pollution in a direct relation to the effect which those conditions exert on the metabolism of the bacteria. The relatively slow movement of ground-water extends the position on the time-concentration curve to the right within relatively short distances from the focus of pollution; the laminar nature of the flow tends to concentrate the bacteria near the capillary fringe into which they are withdrawn when the water-table is lowered; the impermeability of certain strata prevents the passage of bacteria altogether. It may be reasoned that if feces are deposited on the surface of the ground or in the zone of aeration, the rate of downward movement toward the zone of saturation would be slight unless there were sufficient precipitation to cause a positive movement of water through this zone. The experimental data confirm this hypothesis and also the corollary that bacteria reaching the zone of saturation will not survive for indefinite periods of time and that the extent of the pollution will first proceed to a maximum and then recede as clogging fills more and more of the pore space.

Experimentation has been directed toward measuring quantitatively the extent of sub-surface pollution, both bacterial and chemical, in direction, distance and intensity. Most work has been limited to investigation of the travel of pollution in uncompacted strata near the surface where the flow is in capillary channels. It is from these strata that shallow wells derive their water.

A significant contribution to the more recent attempts to evaluate the problem was made by Kliger.[4] The viability of organisms exposed to an unnatural environment was investigated and the results may be summarized as follows from the author's conclusions:

1. Both typhoid and dysentery bacilla succumb rapidly on an exposure to an unnatural environment.

2. In solid feces, typhoid survives from ten to fifteen days, while dysentery is less resistant and paratyphoid more so.

3. In moist natural soils the typhoid and dysentery bacilli may be recovered up to seventy days; in the same soil dry, not after two weeks.

4. Moisture and reaction of the soil are the major factors in survival, while temperature has a lesser effect.

5. Certain soil bacteria exhibit an antagonistic action on typhoid and dysentery bacilla due to the alkaline reaction resulting from their metabolism or as in the case of *B. fluorescens* (Pseudomonas fluorescens) and *B. proteus* (Proteus vulgaris) due to specific inhibitive substances elaborated.

He also concluded that ". . . in moderately compact clay and sand, clay or sandy soil, free from cracks, the possibility of subsoil pollution of the ground water is negligible, provided the ground water level is more than 10 feet below the polluted area."

In 1923 Stiles and Crohurst[5] reported the results of extensive experiments in which the pollution of ground water was correlated with the rise and fall of the ground water table, the flow of ground water and the rainfall. The significant facts developed from these studies were confirmed by later studies by the same men in collaboration with Thomas[6] and the recent work of Caldwell.[7,8]

Stiles and Crohurst[5] state that the results of 27 weeks' experiment showed that:

1. Pollution traveled only in the direction of flow of the ground water.

2. Pollution from fecal B. coli (Escherichia coli) traveled 65 feet from the point at which the pollution was introduced, while chemical pollution (uranin) traveled 115 feet. The sand had an effective size of 0.13 mm.

3. The pollution traveled in a thin sheet at the surface of the zone of saturation. There was no evidence that it dispersed radially downward.

4. As the ground water table fell, the pollution tended to remain in the new capillary fringe.

5. There was no evidence to justify a conclusion that either bacteria or uranin was carried or moved an appreciable distance in the capillary fringe.

6. A rise in the ground water table sufficient to re-establish the zone of saturation resulted in the bacteria being picked up and carried along.

7. The ultimate distance to which the pollution will be carried is dependent on whether conditions resulting in the rise and fall of the ground water table, the rate of ground water flow and the viability of the organisms under conditions of moisture, pH, food supply, etc.

After a period of 2 years, 8 months,[6] the bacteria pollution (*B. coli*) had been recovered at a maximum distance of 232 feet and the chemical pollution (uranin) at 450 feet.

The more recent observations of Caldwell[7,8] should be mentioned. It was found that the chemical pollution from a pit to which excreta was added daily described a path into the ground water, which was the "resultant of the interacting forces of lineal flow with the ground water toward the discharge stream and variations in densities of the effluent flow in comparison to the ground water." Chemical pollution (by analysis) extended through 310 feet. The bacterial stream (*B. coli*) formed an inner core which advanced only slightly beyond 10 feet, after which regression took place. She concludes that the limitation of pollution was due " 'to defense,' clogging of pore spaces of the soil with fine fecal particles and aggregates of colloids and of organisms, which, in addition to the accumulation of sludge, retards flow and hence increases the time for the death rate of fecal organisms to operate."

The experimentation of these workers has provided a quantitative measure of the extent of pollution under certain conditions. From this, some deductions can be made as to the effect of pollution under similar conditions. However, it would be erroneous to apply these measures to problems elsewhere unless there is a considerable similarity in controlling conditions such as porosity of the soil, elevation and fluctuations in the ground water table and hydraulic gradient. The field worker should be guided by consideration of the basic fundamentals, adjusted by experience gained locally, while retaining the results of the experimentation cited as a general background.

Summary

1. The extent of travel of pollutants in ground water is limited in direction, distance and intensity.

2. These limits are controlled by the environmental conditions affecting bacterial metabolism and the nature of ground water flow both in the zone of aeration and the zone of saturation.

3. The viability of the organisms in an unnatural environment is important. The slope of the time-concentration curve is influenced by temperature, pH, moisture and food supply. The more unfavorable these conditions are, the greater will be the diminution in the number of living organisms.

4. The time of ground water flow between the source of pollution and the source of water supply is influenced by precipitation, porosity of the soil and rise and fall of the water table.

5. The filtering capacity of the soil and the clogging of interstices between grains affect the travel of pollution.

6. Careful experimentation has provided a quantitative measurement of the travel of pollution under certain conditions.

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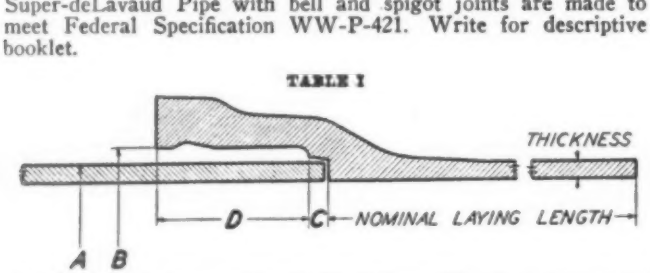
Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length: 12-Foot Length, Weight of Pipe Pounds	12-Foot Length, Weight Per Foot Including Bell	18-Foot Length, Weight of Pipe Pounds	18-Foot Length, Weight Per Foot Including Bell
3	150	.33	140	11.8	210	11.7
3	250	.36	155	12.8	**230**	**12.7**
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length: 12-Foot Length, Weight of Pipe Pounds	12-Foot Length, Weight Per Foot Including Bell	18-Foot Length, Weight of Pipe Pounds	18-Foot Length, Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.13
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.32

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

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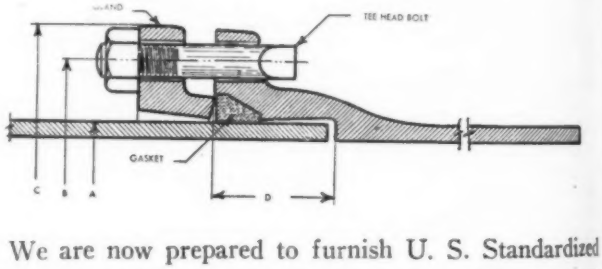

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TRENCHING PRACTICE

By RICHARD BENNETT, C.E.
City Engineer, Phoenix, Ariz.

PART I—EARTH TRENCHING

A TRENCH is an excavation having vertical sides and considerable depth in comparison to its width. For purposes of this article it will be considered as being less than 6 ft. in width and not more than 30 ft. in depth, which permits excavation by modern trenching machinery.

Trenches are dug for all kinds of pipe lines, including water, sewer, gas, oil, drains, conduits, etc. The large amounts of trench excavation made necessary by the installation of pipe lines for the various uses has led to many improvements in this practice.

Many of the early forms of trenching machinery such as the traveling derrick, the trestle cable excavator, the tower cableway, the trestle-track excavator, etc., have all given way to the modern ladder type and wheel type trenchers.

Modern trenching machinery was first perfected about 1910. It gives low cost excavation plus fast rate of progress. It is a part of almost every pipe line construction job. Except for very small jobs, hand trenching labor is generally found inefficient and uneconomical. If the ground is free of large, heavy obstructions, and not too hard, the modern trencher is very efficient.

Type of Trencher Most Suitable

The type of trencher to use will depend upon local conditions. If the trench dimensions are small, and much maneuvering is required because of restricted conditions, then some of the smaller trenchers will prove best.

Many consider the wheel type trencher is a harder digger than the ladder type. In hard and tough clays, for medium depths and widths, this type is most efficient. These designs are generally limited in maximum widths and depths of trenches excavated, the maximum being about 3½ ft. width and 8½ ft. depths.

Where trenches of greater width and depths are involved, the ladder type must be used. If stones, not too large, are encountered occasionally, the ladder type is more efficient to loosen them, being partly due to the vibration of the boom, whereas the steadiness of the wheel type excavator would not accomplish the same result.

On most of the ladder type trenchers the boom may be telescoped so that the depth of the trench may be increased or decreased with little difficulty.

In any case, if the digging is difficult, then the high-powered types must be used.

Some trenchers are designed for use in cramped quarters, such as narrow alleys, parkways, close to curbs, buildings or other obstructions, etc. With some the boom may be shifted to one side so that the trench may be cut close to side obstructions.

Maximum service is desired in a trencher. They are subject to hard, grueling service, and their design should sacrifice nothing which would affect durability.

With modern trenchers the spoil bank may be located on either side of the machine, or loaded into trucks or on conveyor as desired. The spoil conveyor will place the spoil bank back from the trench sufficient distance to give a good clean shoulder on which the workmen are not hindered in laying the pipe. When extensions are added to the spoil conveyor the desired height of the spoil bank may be secured to care for the earth from deep trenches.

Trenching Methods

If the trench is deeper than the trencher will excavate, there are two methods which can be used to gain extra depth without undue expense. (a) Excavate with scrapers sufficient depth from the surface and the full width of the trencher so that the trencher can excavate to desired grade line. Several feet of added trench depth can be secured in this manner. The spoil conveyor can be lengthened so that the earth may be removed either to spoil bank or to trucks as desired. (b) Under most conditions it is possible to remove about two feet of earth below the trencher cut, and throw the spoil back onto pipe already laid in place. Using two workmen, one with air spade and the other to shovel, this work can be done at a rather rapid rate of progress. Using the combination of these two methods, several added feet of depth can be economically secured.

Estimating Practices in Trenching

The trenching contractor is beset with many difficulties and uncertainties, therefore estimates must allow for many unpredictable contingencies. It is impossible to know exactly just what will be encountered until the trench has been excavated. The trenching estimator must judge many factors to the best of his ability.

A visual survey of many jobs will enable the estimator to determine, with reasonable accuracy, whether the job will present many interruptions; on the other hand, too much dependence must not be placed on such surveys in built-up areas. Questions concerning wells, excavations, etc., made previously in the area will reveal many facts. Many pipe line contractors have suffered great losses by not familiarizing themselves with the underground conditions to be encountered.

Parson's "Trenchliner"—250—With Offset Boom
(The boom, now operating at center, may be shifted to any desired position across entire width of chute. Thus the trencher may operate on road shoulders, in narrow alleys, close to curb lines, buildings, trees, etc., without harm or difficulty. The spoil bank can be on either or both sides.)

Cleveland Trencher

(Cutting through a soft-rock formation in Texas called the Austin Chalk. Note the clean cut made. Trenchers of the ladder type are also good in shale, consolidated gravel and all but hard solid rock.)

Much experience is required to properly estimate different conditions and proper methods of pipe line work. Some estimators estimate the job as close as existing data will permit, then add a percentage for uncertainties—a method but little better than a shrewd guess. The estimator who can accurately determine costs on two or more methods for the same job, is worthy of his hire.

In pipe line construction, the cost of trenching is usually the major item, depending upon digging conditions. The kind of earth involved makes much difference in the unit costs. These costs increase according to the types of earth, somewhat as follows: light earths and sand; loam and light clays; dry, hard loams and tough clays; dense and tough adobes; coarse gravels, cemented gravels; hard caliche; and disintegrated granites. All these materials produce different unit costs.

Labor Costs

Labor costs are not materially increased with the light earths, sand loams and clays, but such costs are increased with the tough, dense clays, adobes, varying with the amount of pipe bedding required. Mud, especially if it is sticky, will greatly increase costs. Unforeseen conditions, such as solid rock, boulders, water, caving soil and even quicksand conditions will greatly increase costs.

The estimate must include: excavation, sheeting, backfilling, equipment rental; moving to and from job; and if water is likely to be encountered, then an allowance must be included for water pumping and disposal.

The labor expense will include foremen; machine runners, helpers or swampers; pipe layers; laborers; timbermen; backfillers; as well as extra roustabouts. The cost of superintendence and supervision can generally be estimated as a percentage of the payroll.

Fixed Costs

Fuel, supplies, and equipment repairs will generally be a large item with most jobs. To determine the fixed costs per day, the contractor must make assumptions which are later adjusted in the light of actual facts. Some depreciate trencher equipment at 60 months' total life; however, many individual pieces of equipment have lasted both much longer and even shorter time than this. Some authorities estimate yearly costs of this equipment somewhat as follows: depreciation, 20 per cent; repairs, 18 per cent; interest, insurance and taxes, 7 per cent; miscellaneous, 4 per cent. Total fixed charges per year—approximately 50 per cent of original cost of trencher. The total fixed costs per year divided by the units of work performed gives the actual job cost for using that particular machine.

About 4 per cent of the payroll should be charged for small tools. Miscellaneous materials required for the work as the job progresses will generally average about 1 per cent of the payroll. Small jobs, unless the management is excellent, will produce high unit costs.

Daily Cost Analysis Important

The cost analysis of trenching for every job should show the width and depth of trench; type of soil; the total footage excavated; the number of cubic yards excavated; the total overhead and operating expense of the trencher; the daily expense of trenching; the footage expense of trenching; and the cubic yard expense of trenching.

The unit costs should separate excavation; pipe laying; back-filling; cleaning up, moving to and from job; and overhead. The analysis should show minimum, average, and maximum day's work and reasons, together with average of all items for the entire job. These data, kept up daily, will show and determine all leaks and losses on the job.

PART II—ROCK TRENCHING

What was said in Part I on trench excavation in dirt may also be almost wholly applied to trenching in rock. Rock trenching is a time and labor consuming proposition. The fact that it is not often encountered probably accounts for the great variation of methods adopted on different jobs. The technical literature contains almost nothing on this subject. Ask the manufacturer's blasting experts and they merely say, "I will get you something on that." (Period!)

System Lacking in Rock Trenching

Most rock trenching jobs have little or no system. Costs are high, progress is slow, and those in charge make little or no endeavor to find the most economical method for that job.

In rock trenching the quality and quantity of the rock will generally determine the proper method of excavation. For economical work it is necessary to give much thought and attention to the job methods.

The types of rock encountered may vary from hardpan to dense, tough granites; each will require a different method of drilling and shooting.

There does not seem to be any current standard practice in the spacing of drill holes. Each foreman seems to have his own pet ideas—very few of which would stand much investigation from an efficiency viewpoint.

Proper spacing of drill holes will depend on the nature of the rock and local conditions, but cut and try methods must be utilized to ascertain the most economical method.

Drilling Requirements

The number of feet of hole to be drilled per cubic yard of rock to be excavated will vary greatly with different jobs, conditions and job methods. Spacing will depend upon nature of the rock and width of trench. Properly determining this factor requires much ability on the part of the job manager. This determines ultimate unit costs

For average rock the following table may be used to determine trial hole spacing:

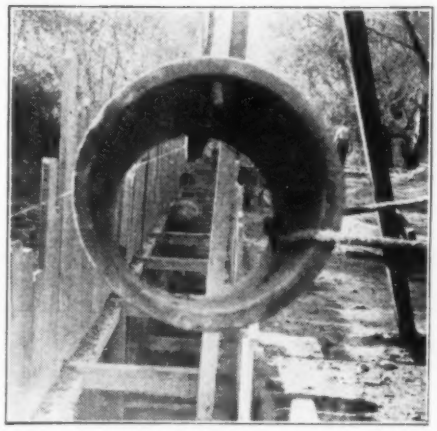
Width of trench (feet)	Number of rows of holes
3	2
6	3
9	4
12	5
15	6

The outside row of holes should be in line with the trench wall. It is seldom that cross-trench hole spacing greater than 3 ft. can be successfully used. At times the longitudinal spacing can be increased to 4 ft. or even slightly more, especially in the wider and deep trenches. The greatest economy is secured in using maximum depth for holes.

The necessity for protecting adjacent structures, whether underground utilities or nearby buildings, will influence drill hole spacing.

If power excavation equipment is to be used, it is seldom possible to blast a single line of holes down the center of the trench. With but one line of holes too much projecting rock remains to be loosened by prying and barring by hand methods, thus greatly increasing costs.

Care must be taken to keep the drill holes clean until they are loaded. If the hole contains debris or water, this is best removed with compressed air. Ice frozen holes may be cleaned out with steam; this also warms the hole sufficiently so that the explosive will not freeze. A wooden plug should be driven into each hole as soon as the drilling is completed, to keep out extraneous materials; this plug also aids in finding the hole later.



A Well Braced Trench

Proper Quantity of Explosives

Determining the proper amount of explosive to use will require trial and error determination. Experience and good judgment helps very much. In any case carefully kept notes and records are of immense value.

In trench blasting only one narrow face is open, therefore more explosive is required than for open surface blasting. The amount and strength of dynamite to properly use will depend upon all the factors mentioned for spacing of drill holes. The amount of explosive required per cubic yard of rock removed will depend upon the nature and type of rock and the method adopted. The amount of explosive per hole may be limited by the necessity for controlling flying rock, excessive noise or vibrations, and danger to nearby underground utilities or adjacent structures of any nature.

Dynamite is generally used for trench blasting; the grade used depending upon the type and quality of rock encountered. The quantity required may range from about ¾ lb. per cubic yard in soft sandstone to 3 lbs. or more in the hard, dense rocks.

Different rocks and formations do not blast alike to meet given conditions. The specifications for the work may limit the amount and kind of blasting that may be done on the job. Oftentimes blasting is restricted due to local conditions.

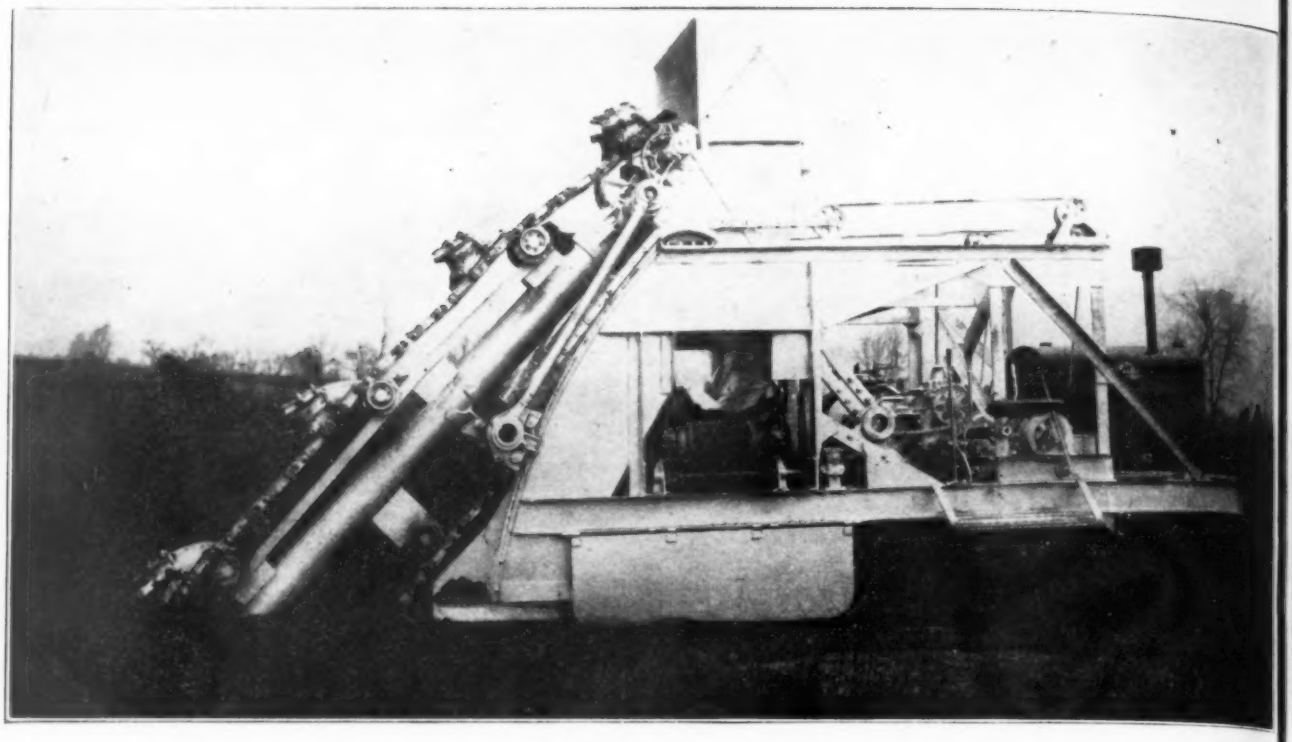
Selection of Proper Explosives

The type of explosive to use will depend upon the type and quality of the rock; local conditions; etc. The greatest waste in explosives is in using a grade or type not suited to the job at hand. A low grade of explosive should be used for soft, weathered rock; to use high grade explosive here, is to waste much of the explosive energy. High power explosives lack propelling power when used in blasting soft rocks.

Too many use only one type and grade of explosive — generally 40 per cent strength. This is poor economy. Some arbitrarily use 60 per cent to secure sufficient shattering and also to loosen rock bound in place. If the rock is not shattered sufficiently, then a higher grade should be used. If the rock is shattered too much, then a lower grade should be adopted for the job.

A high power explosive should be used for hard, firm rock. If the bottom of the hole does not shoot properly, then it may

Koehring's Trench-Hoe
(A rugged piece of equipment, useful where the going is tough—boulders, hard shale, blasted rocks, etc.)



Buckeye Model 120 Trencher
(Buckeye also makes a wheel-type trencher satisfactory for water-line trenching, requiring less depth and permissive of faster travel where the going is easy.)

be best to use a high grade explosive at this point. In such cases place the firing charge at the top of explosives so that the explosive gases will tend to concentrate at the bottom of the hole, thus producing greater rupture at that point.

Sufficient shattering must be secured to permit easy removal of the rock from the trench. It is not possible to use ladder type of trenchers for rock trenching, except in the very soft formations. A pull shovel or trench-hoe may often be used to good advantage in rock trenching.

Rock Excavating Equipment

In shallow trenches the rock may be removed by hand. For hand excavation the rock must be broken into small pieces by either blasting or subsequent breakage.

For deep rock trenches the use of drag line or pull-shovel is most economical. These types of equipment are well suited for this work. The rock must be thoroughly broken up, and the wall sufficiently straight not to hang up the shovel. Rocks too large to be removed by the bucket should be hoisted from the trench with chains.

Limestone is easily drilled. It is occasionally found in horizontal layers, and may be blasted like building stone. In seamy formations, the holes must be closely spaced to retain the force of the explosion. Seamy rocks permit the explosive gases to escape and the full effect is not retained in shattering. Seamy rocks, lying at an angle cause the drills to stick and bind in the hole. Relatively smooth and straight walls may be secured in blasting soft sedimentary rocks.

Granite and igneous rocks break out in rough, irregular walls. If the holes are thoroughly and tightly tamped, then the explosive will give most effective results, due to confining the explosive gases. Trap and quartzite are generally difficult to drill.

Two factors should be kept in mind at all times in rock trench excavation: the number of feet of hole drilled per cubic yard of neat excavation; and the amount and strength of dynamite used per cubic yard of excavation; both of which sum up to: cost of breaking up the rock for satisfactory removal.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

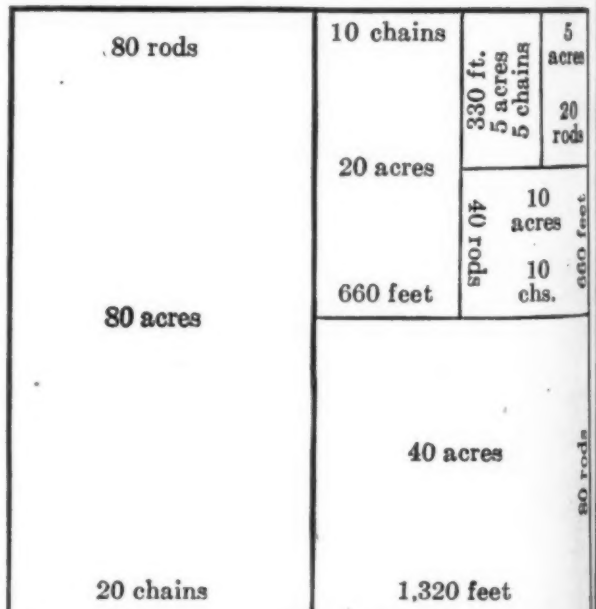
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

An acre is about 208¾ feet square.



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IN CANADA: Atlas Products are manufactured by H. L. BLACHFORD, Ltd., 977 Aqueduct St., Montreal 3; 86 Bloor St. W., Toronto 5

MANUFACTURERS OF

Tegul-MINERALEAD JOINTING COMPOUND

FOR BELL & SPIGOT WATER MAIN

Tegul-MINERALEAD is a radically different jointing compound with advantages not matched in total in any other product for its purpose. Its sulphur base includes, as a plasticising agent, a special olefine polysulphide which contributes these advantageous properties: GREATER ADHESION TO METALLIC AND CERAMIC SURFACES • HIGHER RESISTANCE TO VIBRATION and to MECHANICAL SHOCK AND TEMPERATURE CHANGES • GREATER PLASTICITY and LOWER COEFFICIENT OF EXPANSION.

Using *Tegul*-MINERALEAD you may expect:

SPEED — *Tegul*-MINERALEAD melts, pours and sets quickly and uniformly (a factor in reducing labor costs). Joints show less than usual initial leakage and backfilling may start at once, thus hastening removal of traffic hazards which arise from open trenches.

CONVENIENCE — Molded in 10 lb. ingots, *Tegul*-MINERALEAD is easier to handle, ship and store. The ingot is impervious to moisture so may be stored outdoors in any weather. Since there can be no change of composition in an ingot, *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our factory.

ECONOMY — *Tegul*-MINERALEAD weighs only 1/5th as much as lead (and goes 3 times as far) saving in shipping costs. 5 ingots to carton makes a handy package. It needs no caulking or deep bell holes and requires no skilled labor. The sum of *Tegul*-MINERALEAD'S advantages make it a *money-saver*, too.

RESISTANCE TO SHOCK — Higher resistance to mechanical and thermal shock promises permanently tight joints. Lines laid with *Tegul*-MINERALEAD in every kind of terrain and meeting every kind of punishment, have served for years without need of attention.

AVAILABILITY — *Tegul*-MINERALEAD is stocked at conveniently located points and is usually available on short notice. Using *Tegul*-MINERALEAD helps conserve lead, a strategic war metal.

HOW *Tegul*-MINERALEAD IS USED

MELTING — *Tegul*-MINERALEAD melts at 248°F., requiring only a slow fire. Care should be taken to avoid direct contact with flame and overheating, which tends to cause the compound to thicken. Best results are had by using furnace designed by the manufacturers of *Tegul*-MINERALEAD.

YARNING — The pipe at Bell and Spigot must be clean and free from accumulations of oil, tar and grease. If jute is employed it should be the dry, braided type.

POURING — See that joints are clean. Use mud on asbestos runner to prevent adhesion to the *Tegul*-MINERALEAD and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or pouring pot of sufficient capacity to fill the joint at one operation. Add whole or half ingots to replace *Tegul*-MINERALEAD used. It is not necessary to wait for complete melting before pouring more joints. Cut off pouring gate when compound has solidified. Remove runner and joint is complete.

The HYDE-RO Ring

AN IMPORTANT AID IN BELL & SPIGOT JOINTING

***SPEEDS STERILIZATION*—First hypochlorite flushing invariably secures negative reaction.**

Cross section

PROMOTES ECONOMY — FACILITATES REPAIRS EASILY APPLIED

ADVANTAGES IN DETAIL . . .

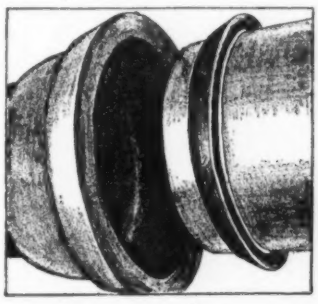
(1) PREVENTS CONTAMINATION — Rubber cannot harbor bacteria nor support their growth internally where water main sterilizing agents cannot reach them. The use of HYDE-RO Rings will prevent continued recontamination that has been traced in many cases to the joint packing.

(2) ECONOMICAL — The cost of HYDE-RO Rings is insignificant compared with the cost of repeated treatments with hypochlorite or the cost of sterilizing and keeping sterile (if it can be done), other types of packing.

(3) CONVENIENT — The installing of HYDE-RO Rings is a simple, easily understood operation. There is no measuring to be done and no cutting. The wrong size cannot be used. Since rings are solid, there are no laps to be inspected to see that they do not occupy too much of the joint space. The same ring fits pipe with bead on spigot or straight end pipe. The narrow iron blade used in caulking the ring automatically slips into the groove in the back.

(4) HOLDS BACK WATER — When HYDE-RO Rings are used, the pouring of wet joints is unnecessary. The rubber ring caulked tightly into place effectively dams off water from leaking valves and permits pouring of dry joints. This is especially important in repair work.

(5) CONVENIENT TO STORE — HYDE-RO Rings are supplied in cartons each containing fifty rings. The packages are light in weight and convenient to handle and store. Rings are manufactured for 4", 6", 8", 10" and 12" cast iron pipe.

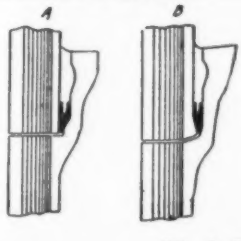


HOW RING IS USED

(1) Stretch the ring over spigot end of pipe with narrow end toward bell.

(2) Slide ring about 1½ inches from end of pipe; then slide the pipe home.

(3) Caulking the ring home, use narrow caulking tool about ⅛" or less in width.



Cross section showing the HYDE-RO Ring caulked into position on plain end (A) and beaded end (B)

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A dependable Joint Compound
for Cast Iron Water Mains

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BOND-O in powder form is a self-caulking jointing compound so carefully blended by modern machines that nearly every joint made with BOND-O is tight when water pressure is first applied. Any slight seepage takes up under pressure in a very short time without further attention.

BOND-O in powder form is made from carefully selected and proven ingredients properly compounded and thoroughly blended. It is in use on several hundred miles of pipe 4" to 60" in diameter and many users claim it is the most satisfactory jointing material they have ever used.

BOND-O in powder form is shipped in a new style guaranteed water-proof bag.

IN INGOT FORM

BOND-O in ingot form is the same carefully machine-blended BOND-O we make as a powder. It is made in 10 pound ingots and shipped in 50 pound cartons (5 ingots to a package). Many users prefer BOND-O in ingot form because of its ease in handling, storing and cleanliness in using. BOND-O in ingot form is impervious to moisture. Compare BOND-O in ingot form with any compound—first in texture, then by actual test—and note the difference.

HYDRANT FLOW GAUGES

with Hand and Hand
& Clamp Pitots

WITH HAND PITOT

NORTHROP Hydrant Flow Gauges meet the need for practical, accurate and simple gauges for conducting Flow Tests from hydrant openings.

The Hand Pitot, as pictured above, is perfectly designed and is equipped with both large air chamber and throttling cock. The Pitot is made with a shoulder to set against the hydrant outlet to steady the instrument and to center the pitot in the stream.

The gauge, manufactured to specifications furnished by the National Board of Fire Underwriters, has two scales, one reading in pounds pressure per square inch, the other in the approximate equivalent in gallons per minute computed for a 2½" open hydrant butt.

Other sets include a combination Hand and Clamp Pitot. This instrument can be used as a Hand Pitot or clamped on the hydrant without damage to the threads.

Another set includes both the Hand Pitot, the Hand and Clamp Pitot, three gauges and a Hydrant Cap Adapter.

OTHER WATER WORKS SPECIALTIES

In addition to manufacturing BOND-O and Hydrant Flow Gauges, Northrop & Company distributes many quality water works specialties. Among these are Marlow Pumps—Test Pumps—Air Valves—Pipe Cutters—Pipe Pushers—Repair Couplings—Generator Sets—Pipe Thawers—Valve Box Locators—Pipe Finders—Leak Locators—Gauges—Gauge Testers—Test Plugs—Air Compressors—Meter Testers—The Meter Master—Meter Seals—Lanterns and Torches.

PIPE MATERIALS†

By A. A. HIRSCH*
State Dept. of Education, Baton Rouge, La.

DURING the continuing but relaxing restrictions on steel, wrought iron, copper-bearing metals and rubber, the water system operator must still utilize other materials, possibly for the duration. This survey has been made to inventory other available pipe stocks and to present their advantages and shortcomings. While the kinds of pipe listed below generally require priority ratings, their adoption in lieu of controlled materials permits availability on desirable and approved projects.

Palliatives

Before planning additional pipe installations for increased capacity, consideration should first be given to the effect of corrective measures in the present system; these restorative operations include (a) pipe cleaning, (b) anti-corrosion treatment of the water, and (c) pipe lining in place.

Pipe cleaning usually restores from 85 to 90 per cent of the original carrying capacity but accelerates subsequent tuberculation unless the water is corrected by anti-corrosion treatment or the pipe interior is covered with a protective lining. A cable drawn scraper is used in pipe sizes down to 2-inch diameter; for 8-inch sizes and larger a pressure driven go-devil may be inserted.

Anti-corrosion water treatments are of several types. The calcium carbonate saturation method is the most widely adopted practice; the desired condition borders on calcium carbonate equilibrium which may be attained, according to the specific case, by (a) aeration for carbon dioxide removal, (b) addition of the alkalies lime or sodium carbonate to increase the pH value, calcium or carbonate concentration, (c) injection of caustic soda when simple pH increase suffices, (d) passage through limestone beds to increase the calcium concentration, alkalinity and pH, and (e) any proper combination of these methods. A calcium carbonate deposit on rough lines or from highly supersaturated solution may be attenuated and distributed over a wider area by impeding crystallization through the use of sodium hexametaphosphate. This material is also widely successful in inhibiting corrosion. A special slowly dissolving form, sold as "Micromet," is adapted to anti-scaling and anti-corrosion protection of domestic hot water lines. Other effective inhibitors are sodium silicate and proprietary organic products, mainly plant extracts. Corrosion of bacterial or plankton origin may be controlled by supplying dissolved oxygen or by some variety of chlorination, usually chloramination or break-point dosage.

Pipe lining in place is limited at present to cement mortars; these reduce the bore slightly but smooth the walls. The overall effect is a gain in stability and hence in long term delivery. In the Tate process a centering mandrel is pulled through the cement mortar thereby squeezing a thin coating on the walls; this method is adapted for use in small and medium sized mains. In 30-inch and larger lines the "Centriline" method is employed, in which a centrifugal machine slings the mortar forcibly against the pipe walls where it is mechanically troweled to a smooth dense lining.

Extensions

When additional piping is required for extensions of service, this need obviously can be satisfied only by new construction, and in such instances recourse to alternate and substitute materials is in order. As amended January 22, 1944, the U-1 order permits: (a) new construction not exceeding $1,500, (b) domestic extensions which do not require more than 400 pounds steel, 1,800 pounds cast-iron, or 1,000 pounds of lead products, or combinations of these materials as stipulated, (c) use of any materials for mains 4 inches and smaller, (d) use of cast-iron and the non-metallics for mains larger than 4 inches but with steel allowed where special conditions warrant, and (e) an unrestricted procurement for inventories totaling less than $10,000 instead of the previous 60 per cent limit. Non-metallic pipe is restricted to a length not exceeding that if cast-iron were being used. Certain essential extensions for the military or industry may be built valued to $5,000.

Copper tubing, frozen in inventory, has been released by Supplementary Order U-9-c-4, amended January 24, 1944, but only for underground service outside buildings. The WPB Utilities Order U-1, issued February 24, 1943, assigns an AA-1 rating to water systems for maintenance, repair, operating supplies and replacement materials following a breakdown.

Alternate and substitute pipe line materials may be grouped for purpose of discussion into the following classes: (1) cement products, (2) metals, (3) plastics, (4) limited use materials, and (5) impractical specialties.

Cast-iron pipe, on which restrictions are the mildest, is so familiar that discussion is supererogatory. Screw joint service pipe of cast -iron is produced in sizes from 1¼ to 2 inches, and is procurable with cement linings.

I. CEMENT PRODUCTS

I.1 Concrete Pressure Pipe

Tentative emergency specifications for reinforced concrete pressure pipe have recently been prepared by the American Water Works Association.[1] Three types of pipe are covered as listed below to show the range of sizes and working heads:

Class	Designation	Sizes, in.	Max. operating Head,-feet
A	Steel cylinder reinforced	20-150	600
B	Poured non-cylinder reinforced.....	20-150	100
C	Centrifugal reinforced	6-84	150

This material is being increasingly selected for raw water transmission lines, especially through swampy terrain. A 33-mile length of 39-inch bore Class A pipe has recently been described.[2] Long feeder mains, having a minimum of fittings, is their principal application to distribution systems, particularly if the water is corrosive. In Chicago two miles of 36-inch pipe, Class C, were laid to supply a new war plant.[3] This installation was with Lewistown Prestressed pipe in which the inner layer was spun in a centrifugal form strung through longitudinally with strained rods and then steam cured before wrapping with stretched steel wire to produce a compression in the pipe wall. A 1-inch concrete layer poured around the wire protected it against soil corrosion. No difficulty is experienced with concrete pipe in satisfying the leakage limitation of 250 gallons per inch diameter per mile per day. Shallow well casings, perforated screens, culverts and sewers are other uses.

Joints are of three types: collar, lock joint with reinforcing tied together and plastered, and bell and spigot.

Sources

American Pipe & Construction Co., P. O. Box 3428, Terminal Annex, Los Angeles, Calif.
Concrete Conduit Co., 899 La Cadena Ave., Colton, Calif.
Gifford-Hill Pipe Co., 412 Texas Bank Bldg., Dallas, Tex.
Hume Pipe of New England, Inc., Swampscott, Mass.
Lewistown Pipe Co., Hillside, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Price Brothers Co., P. O. Box 825, Dayton, Ohio.
Spokane Concrete Pipe Co., P. O. Box 1033, Spokane, Wash.
United Concrete Pipe Corp., 1347 W. 208th St., Los Angeles, Cal.
Utah Concrete Pipe Co., 1212 S. State St., Salt Lake City, Utah.

Concrete Well Screen

Kelly Well Co., Inc., Grand Island, Nebr.

I.2 Asbestos-Cement Pipe (A/C Pipe)

Asbestos-cement pipe is made from a mortar containing equal volumes of asbestos fiber and Portland cement; this mixture on a weight basis is 15 per cent asbestos and 85 per cent cement. Already familiar in the water works field, this material ranks competitively against iron and steel lines and hence is more than merely a substitute. Experimental manufacture started in 1913. Its first application was as a sea water conduit in Italy to furnish fire protection and a water supply for flushing streets. Some 40,500 miles of A/C pipe had been installed throughout the world prior to the outbreak of World War II.

Federal specifications SS-P-351 cover quality of cement-asbestos piping for government use. The National Board of Fire Underwriters has examined and reported favorably on these products, from outstanding American manufacturers, for use in distribution systems.

Advantages of A/C pipe are its light weight, resistance to corrosion by sodium chloride, hydrogen sulfide, carbon dioxide and dissolved oxygen in water, inertness to soil reaction and electrolysis, permanent wall thickness not reducible by corrosion, salvage value for relaying, ease of cutting with a handsaw, it may be tapped the same as cast-iron (a separate tap is advised to be used on this material only), installed cost is claimed to be 20 to 30 per cent lower than with ferrous piping although the

*Director, School on Water Supply and Sewerage.
†This article was prepared during the war, when restrictions on all materials, including pipe, made consideration of substitutes a necessity. Many of these so-called substitutes have their place in normal times, and therefore this comprehensive survey is applicable for the future.

price f.o.b. is competitive, and its Williams-Hazen flow coefficient may be conservatively taken as 140.

The characteristic disadvantage of A/C pipe is its low structural strength, approximately one-quarter that of an iron line. This is reflected in the strength of threads for corporation cocks and in its susceptibility to direct loading. A minimum cover of 2 feet is recommended.

Domestically manufactured products described below are: Transite, Century, Eternit and Roxite. Foreign products are trade named: Duralita, Everite, Durabest and Italite.

1.2.1 Transite A/C Pipe

Transite pipe is formed under pressure, as a homogenous mass, over a full length rotating steel mandrel and is then steam cured to accelerate hardening. Before shipment each length is tested at four times the expected working pressure.

Seventeen sizes are available from 3 to 36 inches diameter. A 2-inch size is used as a taper fitted electrical conduit. Pressure classes are 50, 100, 150 and 200 p.s.i. Standard length is 13 feet. Above the 8-inch size an adapter is needed when jointing into a cast-iron bell.

The joint, a Simplex sleeve, is jacked into position over two rubber sealing rings. As this joint lacks pull-out strength, buttressing is required at sharp bends. The flexibility of the rubber rings permits a 12° deflection without leakage; this property has been found valuable in accommodating soil subsidence and earth movement near bomb craters. Gum rubber rings are reported to retain a high degree of elasticity after many years in service, the oldest record being 66 years.[4] An interesting advantage gained by resilient seals is the reduction of water hammer pressures to about 72 per cent of that developed in a similar cast-iron line.[5]

Source

Johns-Manville Co., 22 E. 40th St., New York, N. Y.

1.2.2 Century A/C Pipe

This pipe is formed in six overlapping plies spirally wound over a mandrel under pressure. Available sizes range from 2 to 12 inches, in lengths of 10 and 13 feet. Standard pressure classes are 100 and 150 p.s.i., but 200 p.s.i. piping may be produced as a special. The joint, a malleable iron Dresser compression coupling, which permits 4 to 6 degrees deflection in the line, has the advantage of being connected simply with a wrench.

Source

Keasbey & Mattison Co., Ambler, Pa.

1.2.3 Eternit A/C Pipe

This pipe, introduced just recently, is formed by the extrusion process, which method is claimed to allow superior control on density and accuracy. Diameters up to 6 inches are available in 13-foot standard lengths.

Source

The Ruberoid Co., 500 Fifth Ave., New York, N. Y.

1.2.4 Roxite A/C Pipe

Roxite is manufactured by high pressure extrusion and deairing to produce a dense, strong wall. For severely corrosive duty a resin coating or impregnation provides protection. Sizes range from ¾ to 8 inches ordinarily, but larger pipe up to 12 inches are furnished on special order; lengths are supplied up to 14 feet. Thicknesses are designed to withstand 150 p.s.i. working pressure. Couplings are patented "Flexlock" rubber sleeves.

Source

The United States Stoneware Co., Akron, Ohio.

2. METAL

New metal products to replace the familiar galvanized iron, copper, brass and lead piping and tubing are available only in small diameters. As previously noted, copper may be used only from stocks on hand or procurable from other water utilities. No priorities are involved in obtaining lead or lead alloy service pipe. Wiping solder and brass nipples are permitted by government orders to complete the installation.

2.1 Asarco "Tube-Loy"

This metallic pipe is extruded from essentially pure lead alloyed with 0.015 per cent magnesium, 0.02 per cent calcium and 0.23 per cent tin to increase its hardness, shock resistance, strength, stiffness, ductility and improve its joining properties but reduce its creep rate. This alloy hardens with age and is corrosion resistant except with the more aggressive waters, in which a too high lead pickup may ensue. Its weight is lighter and cost is less than for AA lead pipe. A salvage value may be realized by remelting old tube-loy pipe to obtain scrap lead.

Type A resembles the conventional AA lead services, with added strength. Sizes range from ¾ to 2 inch. Joints are wiped or sweated.

Type K, suited for pressures up to 125 p.s.i., is thinner and uncoils easily. Sizes are ⅜, ½, ⅝, ¾ and 1 inch, coiled in 30, 45, 60 and 100 foot lengths. Joints may be wiped or sweated as above. Grinnell galvanized malleable iron "Superseal" flared fittings with a long 10° taper permit strong connections for domestic piping. A 45° flare in superseal connectors is also used.

Source

American Smelting & Refining Co., 120 Broadway, New York.

2.2 Bundyflex Copper Coated Steel

The copper coating both inside and outside of this steel tubing is fused on at high temperature into the pores of the base metal, and is claimed to form a copper-steel alloy. This product is soft, ductile, flexible, can be flared, soldered, brazed or welded. It can be used with any of the fittings ordinarily used with copper tubing, either sweat or compression type. This tubing is twice as strong as copper and has much higher resistance to vibration fatigue. Ultimate bursting strength varies from 5,000 to 25,000 p.s.i., depending on the wall thickness and diameter of the tubing. It is widely used by manufacturers of automobile hot water heaters. Sizes range from ⅛ to ⅜ inch o.d. in 25-foot coils, and from 7/16 to ⅝ inch in 12-foot lengths.

Source

Everhot Products Co., 2055 W. Carroll Ave., Chicago, Ill.

3. PLASTIC PIPE AND TUBING

Plastics, in general, are synthetic resins of high molecular weight polymerized from simple compounds by means of heat, pressure and catalysis. Based on composition, plastics have been grouped by the Plastics Catalog[6] into sixteen basic varieties, each with characteristic properties which adapt them to special applications. About 250 trade names of plastic compositions are now produced. For fabrication into pipe and tubing, materials are desirable which can be formed by dry extrusion, as this is the most efficient method of manufacture and produces tubing of unlimited length. Only a few specialties in the way of tubing are now produced by lamination. The strategic demand for certain of these resins places further limitations on the availability of pipe stock.

Present plastic compositions invading the pipe and tubing market belong to the polyvinylidine chloride and cellulose acetate butyrate types. These elastomers are replacing metal and rubber conduits for defense structures, battleships, army caps, stirrup pumps and similar applications. Also a variety of specialty tubes is being produced from other types of resins for specific applications, mainly in connection with the war effort. According to the concensus of present opinion no serious displacement of the metals from water pipeline service is foreseen. However these prophesiers fail to appreciate obvious advantages peculiar to some plastics. A plastic pipe will usually eliminate need for protection against freezing; neither will it corrode. In domestic hot water lines the temperature drop between heater and fixture will be minimized; acid may be used with impunity for scale removal. Light weight and visibility, with some types, are other desirable features. In Germany, Mipolam, and in the U.S.S.R., Textolite are plastics substituting for metals in water supply systems.[10] Only the three materials described below are of immediate interest, but when peace returns, other plastic compositions will undoubtedly become available for water supply specialties.

3.1 Saran

Saran, a flexible, yellowish, translucent polyvinylidine chloride product, which is replacing copper tubing in approved housing projects at a comparable cost, so far has been the principal and most promising plastic offered for water services. Its tensile strength ranges from 4,000 to 8,000 p.s.i. Hot water temperatures to 170° F. are withstood continuously; up to 212° F., intermittently. Saran does not support combustion; it is rated as self-extinguishing, however, since it melts near 310° F., fire or high temperature is destructive. Sunlight darkens its color, so pipe intended for exposure is black.

In a study of its properties for the National Association of Master Plumbers, Dawson and Kalinske[9] reported that Saran piping is hydraulically smooth, and water hammer pressures, by virtue of its elasticity, were only ½ to ⅓ as great as in iron

pipe. As its heat conductivity is only 1/4,500 that of copper, frost protection in services and inappreciable temperature loss in hot water lines is afforded. Deposits do not tend to adhere. White rats were observed to attack this material if starved or thirsty. Saran pipe expands 0.83 feet per 100-foot length per 100° F. temperature change, therefore distortion must be controlled. Low temperatures cause an embrittling effect.

At a magnesium plant, the electrical insulating properties of Saran enabled replacement of less durable rubber pipe for water jackets in rectifiers without grounding across 600 volts.[8]

Black Saran pipe is available in ½, ¾, 1, 1¼, 1½, 2, 2½, 3, 3¼ and 4-inch sizes. Its weight is one-quarter that of corresponding iron pipe. Bursting pressure varied with size from 620 to 1,500 p.s.i. at room temperature. A representative line of molded Saran screwed fittings is made. Joints may also be made by autogeneous welding after first melting the abutting ends on a hot plate at 400° F., or by a portable girth type electric heater.

Flexible tubing, of high fatigue strength, is furnished in various wall thicknesses from ⅛ to ¾ inch outside diameter. Bursting pressure, dependent on size, varies from 580 to 1,200 p.s.i. at ordinary temperatures. Couplings are the flared compression type, molded from Saran resin.

Source

The Dow Chemical Co., Midland, Mich.

Licensees

Extruded Plastics, Inc., New Canaan Ave., Norwalk, Conn.
Haveg Corp., Newark, Del.
Hodgman Rubber Co., Framington, Mass.
Godall Rubber Co., Inc., 5 S. 36th St., Philadelphia, Pa.
Elmer E. Mills Corp., 153 W. Huron St., Chicago, Ill.
Western Felt Works, Acadia Synthetic Products Division, 4035 Ogden Ave., Chicago, Ill.

Distributors

American Radiator & Standard Sanitary Corp.
Crane Co.
Metal Goods Corp.

3.2 Tenite

Tenite II is a cellulose acetate butyrate plastic made according to the manufacturer's formula 201 in transparent varieties and formula 205, containing an ultraviolet inhibitor, in the opaque, gray type. At low cutting speed it machines like metal. By immersing in hot water it may be shaped to curves. A test piece holding 80 p.s.i. water pressure for over two years held its dimension within 2 per cent. Rodents and insects are not attracted, according to claim. It is a definite fire hazard, being rated similar to bulk newsprint. Hot water temperature is limited to 140° F.

Sizes range from 3/16 to 2½ inches in 29 items. Heavy wall tubing is cut in 8 to 12-foot lengths; 20-foot lengths are specials. Joints are made either with flared end compression fittings or by heat expanding one end to receive the mate in telescope fashion, then sealing with a suitable solvent in Duco cement.

Source

Tennessee Eastman Corp., Kingsport, Tenn.

Licensee

Extruded Plastics, Inc., New Canaan Ave., Norwalk, Conn., (Lists as Tulox TT seamless tubing.)

3.3 Plastitube and Plastiflex

These are rigid and flexible tubing, respectively, extruded from cellulose acetate butyrate in standard 12-foot length and 60-foot coils. Sizes range from ⅛ to 2 inches outside diameter.

Source

R. D. Werner Co., Inc., 380 Second Ave., New York, N. Y.

4. LIMITED USE OF PIPE

4.1 Orangeburg Fiber

This light weight pipe is composed of 25 per cent cellulose fibers and 75 per cent coal tar pitch. The fibers are first felted and dried, then impregnated under vacuum to assure complete penetration. Advantages of fiber pipe are its economy, toughness, ease of cutting, light weight (16 per cent that of steel), protection against freezing, high flow factor and absence of corrosion. In shrinking soils it deflects with settlement but does not crack. Its principal disadvantage is that use must be confined to low head or non-pressure applications, such as for vents, downspouts, drains, chemical feed conduits and tile sewage disposal fields. When used for sewers its tight tar joints are claimed to prevent entrance of roots. Its inertness permits use in oil fields brine disposal systems. When laid underground it must be well covered and tamped; if suspended, rigid supports are needed to prevent sagging. Even were this piping suitable to carry drinking water the coal tar impregnate would likely cause chlorphenol tastes with free chlorine. Its short length is something of a drawback.

Sizes are 3, 4 and 5-inch diameters in 8-foot lengths and 6 and 8-inch diameters in 5-foot lengths. Fiber fittings include bends, ells and adapters for connecting either to threaded or to bell and spigot pipe.

Joints are made by driving a 2° tapered sleeve over a corresponding taper on the pipe ends. A field tooling lathe is supplied to dress a taper on job cut lengths. Cementing compound is unnecessary as the friction is claimed to develop sufficient heat during driving home to soften the pitch and thereby seal the joint. A pull of 1,500 pounds is required to separate the joint in a 4-inch pipe.

Source

The Fibre Conduit Co., Orangeburg, N. J.

Distributor

Crane Co.

4.2 Wood Pipe

Pine, fir, redwood, red cedar and cypress are the species selected for making wood pipe. The bored type is available up to 4-inch diameter in 12-foot lengths. Large quantities are being shipped overseas for army use. The banded type is assembled from tongue and groove staves, machine strapped at the factory with galvanized bands, covered with pitch and rolled in wood shavings. Large sizes are assembled in the field as a continuous cylinder, bound together with rods and lugs. Such pipe is widely used for penstocks under heads as high as 150 feet. This pipe is suitable for raw water transmission from a distant source to the treatment plant. The preferred method for installation is either deep burial or support on racks with allowance for ventilation underneath. Surface installation allows premature decay at the ground line. Termites do not invade the wood if saturated with water. Lines for intermittent use are pressure creosoted.

Advantages of wood pipe are cheapness, light weight, fairly long life—from 20 to 50 years, depending on circumstances—high stable carrying capacity, frost resistance, absence of expansion joints and freedom from soil corrosion and electrolysis effects, except at the metallic binders. Its disadvantages are danger of collapse from weight of backfill, particularly if empty or under vacuum, ground line decay where resting on the soil and possible failure from corrosion of the retaining bands. High leakage losses are experienced, especially under varying pressures. Since water distribution systems are subject to continual water hammer, wood pipe is definitely unsuited for this application. Leaching of color and resins decreases with age.

Machine banded pipe for working heads up to 250 feet is available in sizes from 6 to 48 inches and in lengths from 12 to 20 feet. A lap joint or collar, wood or metal, is used for connections. Continuous stave pipe is obtainable in diameters from 12 to 192 inches. Joints in the staves are staggered within a short segment so that additional tension rods placed there can provide rigidity. A tapered steel tongue is driven into the butt ends of the staves to secure positive connection.

Sources

W. E. Caldwell Co., 2236 Brook St., Louisville, Ky.
Federal Pipe & Tank Co., 6851 E. Marginal Way, Seattle, Wash.
Michigan Pipe Co., 504 Phoenix Building, Bay City, Mich.
National Tank & Pipe Co., 2301 N. Columbia Rd., Portland, Ore.
Redwood Manufacturers Co., Hobart Bldg., San Francisco, Cal.
A. Wyckoff & Sons Co., 1 Home St., Elmira, N. Y.

5. JUTE SUBSTITUTE

Fibrex, a sanitary paper packing with twisted pulp core and braided jacket, treated to retain sterility, may be packed into a joint the same as jute.

Source

Hydraulic Development Co., 50 Church St., New York, N. Y.

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5. Russell, G. E. "Pipe Line Surge and Water Hammer." N.E.W.W.A. winter meeting 1941, reported in Water Works and Sewerage, 88, 119 (1941).
6. Plastics Catalog (1942) Plastics Catalog, Inc., 122 E. 42nd St., New York, N. Y.
7. Dé Bribéré, Maurice. "Conduits Made of Plastic Materials." Bull. Assoc. Chim., 58,175 (1941).
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9. Anon. "Plastic Pipe and Power." Chem. and Eng. News 21, 1052 (July 10, 1943).

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Ratio Indicating Gauges • Flo-Gage
Chronoflo Conveyor Scales • Manometers
Meters for Open Flow • Chronoflo Telemeters
Propeloflo Meters • Auxiliary Equipment

VENTURI METER

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of a Venturi Tube installed in the pipe line and a Type M Register, Indicator, Recorder or other instruments connected to the Tube by small pressure pipes. The design of the Herschel Standard Venturi Tube produces a maximum recovery of pressure, thus having the economic advantage of lowering pumping costs. Bulletin 354.

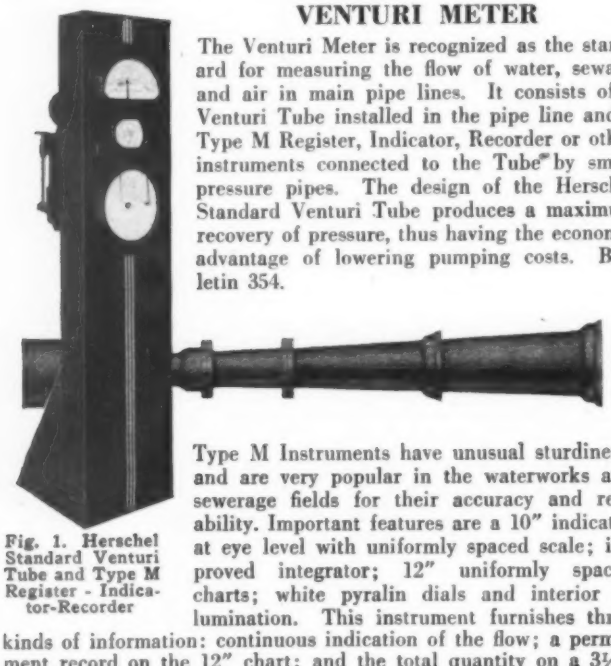


Fig. 1. Herschel Standard Venturi Tube and Type M Register - Indicator-Recorder

Type M Instruments have unusual sturdiness, and are very popular in the waterworks and sewerage fields for their accuracy and reliability. Important features are a 10" indicator at eye level with uniformly spaced scale; improved integrator; 12" uniformly spaced charts; white pyralin dials and interior illumination. This instrument furnishes three kinds of information: continuous indication of the flow; a permament record on the 12" chart; and the total quantity on a 3½" counter dial. All dials graduated in direct reading units for the particular line being metered. Bulletin 324A.

PROPELOFLO METER

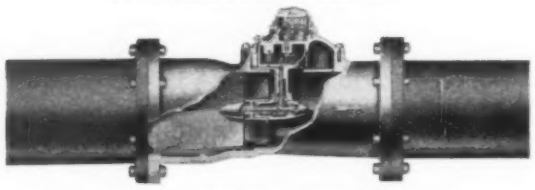


Fig. 2. Propeloflo Meter flange mounted. Available also in bell and spigot model.

This improved, propeller-type flow meter for main water line metering introduces many new features including streamline Venturi design. A self-contained unit easily installed; registers total flow directly in gallons. Accurate throughout wide range; low loss of head; low first cost and upkeep. Bulletin 350A.

FLO-WATCH

A small, medium-priced mechanical instrument universally applicable for use with Venturi Tubes, Nozzles, Orifice Plates and Weirs; available in a variety of mountings and dial combinations. Bulletin 318B.

MANOMETERS

Model MAB, especially suited for test and experimental work, is a simple, accurate flow rate indicator with scale graduated directly in flow units. Has rugged floor stand, protected, easy-to-read glass tube and heavy well with built-in by-pass valve. A Double Tube Manometer and a variety of two-stage inclined manometers also available. Bulletins 343A and 222A.

FILTER CONTROLLERS

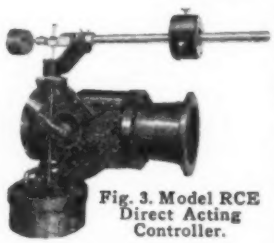


Fig. 3. Model RCE Direct Acting Controller.

Several models are offered, each designed for particular conditions, to automatically maintain constant flow rate through the filter bed. Model RCE features smooth, unwavering control; low loss of head; sturdy, balanced valve; compact flexible design; powerful "floating piston" and exclusive molded tapered piston seal. All rotating bearings anti-friction. Modified for higher pressures and velocities, these controllers serve as Wash Water Controllers or in the effluent lines from pressure filters. Bulletin 321A. Models RCA and RCB are hydraulically operated. Model RCA has a gate type valve with specially shaped seat. Model RCB has a special double butterfly valve of rectangular section and is used for lines over 12" diameter. Bulletin 325A.

FILTER GAUGES

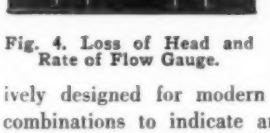


Fig. 4. Loss of Head and Rate of Flow Gauge.

Filter Gauges are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display accurate information gathered by the dependable Builders Diaphragm Pendulum Units. Attractively designed for modern plant interiors. Available in many combinations to indicate and/or record Rate of Flow, Loss of Head, Liquid Level and Sand Expansion. Special types are custom built to engineers' specifications. Bulletin 329A.

KENNISON NOZZLES

Accurately measure flow through partially filled pipes, sewers, and open channels where there is wide range of flow rates. Particularly successful on measurement of raw sewage, sludge and trade waste. Available in sizes from 6" to 36". Bulletin 334A.

CHRONOFLO TELEMETERS

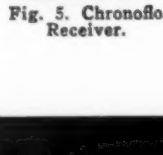


Fig. 5. Chronoflo Receiver.

Chronoflo Telemeters bring to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflo Transmitter. Bulletin 320B.

DETERMINING THE CONDITION OF MAINS

How to Watch Your "C" Line for Friction Losses

By D. R. TAYLOR
Plant Superintendent, Water Department
Roanoke, Virginia

THERE are men who report to their physicians regularly for physical examinations. These men are not concerned about the surface of their anatomy—they can see that; they want to know the trend of that part of their "human plant" that is under the surface.

Among other things, they want to know the friction loss in their circulatory system, and if an increase of this friction is causing a diminution of capacity and a corresponding dissipation of power. They are anxious to take immediaate and proper remedial action if the friction is building up too fast and capacity is falling.

How Are Your Water Arteries?

Realizing that probably 80% of the worth of your water works "anatomy" is represented by its "arteries," also hidden under the surface, leads to the question—How *old* are your water supply arteries? And I do not mean in years, but in the matter of "oldness" in terms of that all important criterion—friction build up and failing capacity. Only if you are watching your "C" line will you know; otherwise you can only be guessing.

How to Find Out

The "C" Line I refer to is no other than the important line to show the status and trend of the coefficient of friction of pipe lines which you have frequently heard referred to as the "C" value of mains.

Determination of the "C" value derived from the famous Williams & Hazen formula may sound formidable and difficult but it really is not and I hope to be able to convince you of as much by showing how relatively simple it is to secure the needed test readings on a length of main and derive therefrom the "C" value (friction coefficient). In short, how you can answer the question—How old are your "arteries"?

This type of work is not only interesting but is full of surprises. It is the most positive and effective method of determining the necessity for reducing the friction in these important arteries and the need for treatment to prevent corrosion. Then, afterwards, what the results of such treatment are. Likewise, if there are advantages to be gained in the use of lined pipe. Finally, as an added guide in planning future developments and additions. After you have selected and tested sections of representative mains, you will have enough curiosity to make a second test within six months, after which an annual check-up is usually sufficient, depending upon results obtained.

The computations necessary are not as intricate as the average water works operator seems to think they are. You need not worry about being "rusty" in the use of a slide rule and unfamiliar with logarithms. You do not need to have a dizzy spell when you see the formidable looking formulae.

A Simple Method of Finding "C" Values

Herewith is a tabulation of diameters and areas of both pit cast and super deLavaud Cast Iron pipe which is self-explanatory, and, although "slipped off" on a slide rule, is sufficiently accurate for the work. I am also enclosing a data sheet presenting two logarithmic curves, the necessary formulae, conversion factors and explanation of symbols. These are all that I find necessary for ordinary purposes in solving flow problems.

In the upper right hand corner of the graph sheet are the simple formulae for determining quantity, velocity, and areas. Formula (1) in the center of the sheet is the original Williams and Hazen formula for the solution of velocity. It is more simply expressed in formula (2). Formula (3) is that employed in calculating these "C" values. Formula (4) is for the solution of "S," which represents hydraulic slope or friction loss. Formula (5) gives the same value more simply.

Procedure

Suppose that you are testing a section of unlined pit cast main with a nominal diameter of 10 inches. Say it is 800 feet long between pressure gauges, and that the measured rate of flow from the hydrant at the far end was 1036.8 gallons per minute. Let us say that the pressure drop between stations (shown by the difference in readings of the two pressure gauges) was 7.13 lbs./sq. in. This represents the friction loss (S) for the 800 ft. run between these two points.

Now, what is the coefficient of friction ("C" value) of this main?

By reference to the formulae on the data sheet we will find that

$$Q = 1036.8 \text{ g.p.m.}$$

$$Q = \frac{1036.8}{448.83} = 2.31 \text{ c.f.s.}$$

$$V = \frac{Q}{A} \text{ and } A = .5454$$

(10" pipe table 1.)

$$V = \frac{2.31}{.5454} = 4.225 \text{ ft./sec.}$$

The hydraulic radius of 10" pipe
$R = .2083$ (from table).

Friction loss (hydraulic slope)
$S = 7.13$ lbs./sq. in. (for 800 feet).

Convert to feet loss
$= 7.13 \times 2.31 = 16.47$ feet.

Per foot of main:

$$S = \frac{16.47}{800} = .0206.$$

Now for the formula:

$$C = \frac{V}{1.318\ R^{0.63}\ S^{0.54}} \text{ in which}$$

$$R^{0.63} = .2033^{0.63}$$

Although shown in the table, this value can be secured from the graph as follows: On the base line, we locate .2083 (R). From this point, move vertically up the sheet to intersect diagonal "B"; thence horizonally to the vertical axis, where we find 0.372. Therefore $.2083^{0.63}$ is 0.372.

In a similar manner, by intersecting diagonal "A," by following up the .0206 (S) line from the base, we find:

$$S^{0.54} = (.0206^{0.54}) = .1225.$$

Therefore; according to the formula,

$$C = \frac{4.225}{1.318 \times .372 \times .1225} = 70.3.$$

In use of formula (5), by employing curve "A" in reverse," any number to the 1.85th power can be had.

For instance, using the above values in formula (5)

$$S = \left(\frac{4.225}{1.318 \times 70.3 \times .372}\right)^{1.85} = .1225^{1.85}$$

Find .1225 on the vertical axis, move horizontally to the right to diagonal "A" and then drop down to the base line, and we find .0206.

Therefore; $S = .0206$.

In order to be as brief as possible this explanation may require a little close study. However, the information should prove sufficient for fairly accurate evaluations.

Let me warn you though to caliper the hydrant nozzle through which the rate of flow is determined. Contrary to the common assumption, this diameter is rarely exactly 2½ inches.

If, after you have pursued this task for a while, your enthusiasm becomes more acute and the magnitude of your study warrants it, you might purchase two calibrated precision altitude gauges to replace your pressure gauges and a K. & E. log-log duplex decitrig slide rule, which is not nearly as difficult to use as you might think. With the use of the log-log scales on this rule, you can accurately and quickly determine the fractional powers

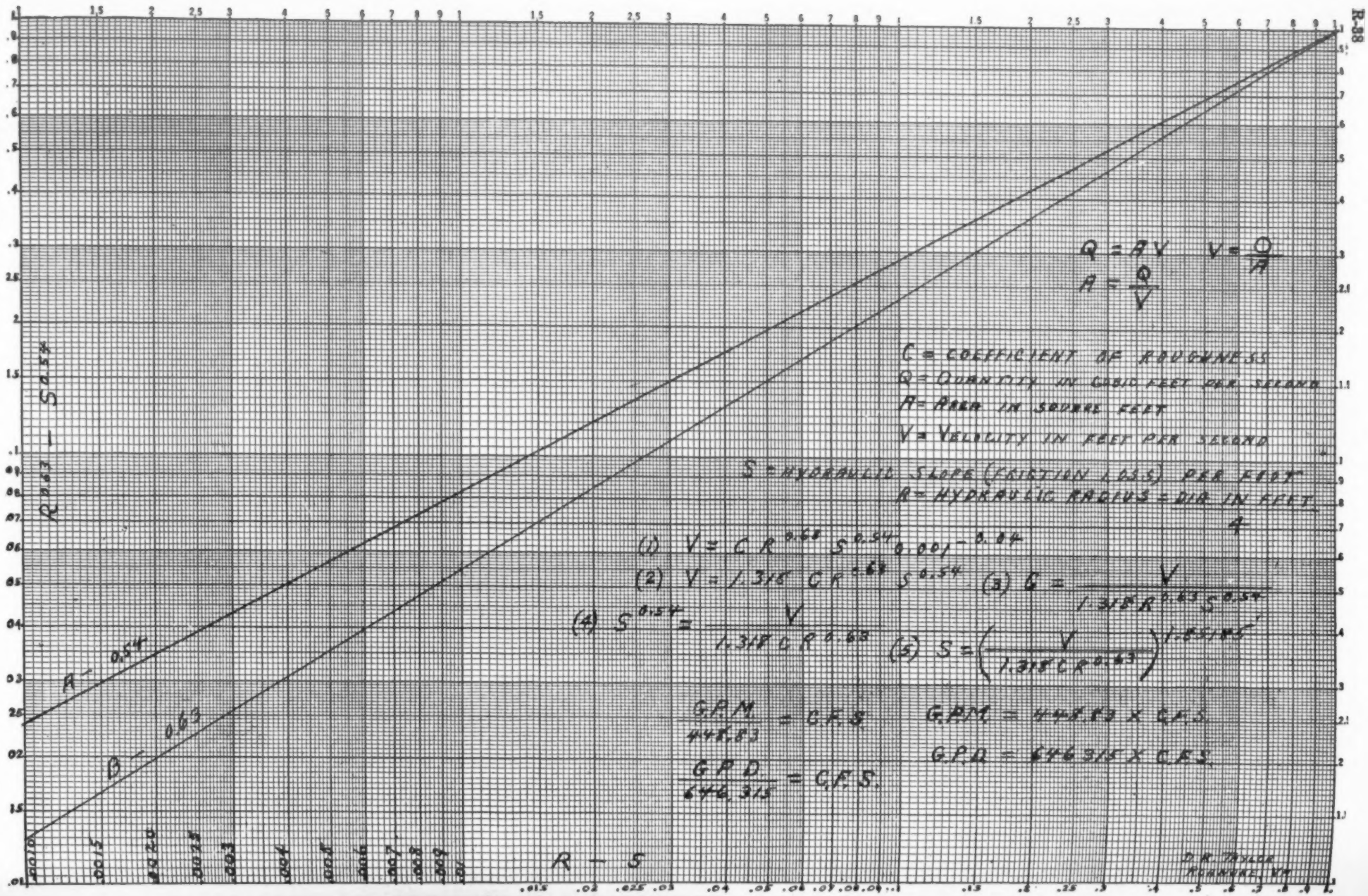

Q = AV V = Q/A
A = Q/V
C = COEFFICIENT OF ROUGHNESS
Q = QUANTITY IN CUBIC FEET PER SECOND
A = AREA IN SQUARE FEET
V = VELOCITY IN FEET PER SECOND
S = HYDRAULIC SLOPE (FRICTION LOSS) PER FOOT
R = HYDRAULIC RADIUS = DIA. IN FEET / 4
(1) V = C R^0.63 S^0.54
(2) V = 1.318 C R^0.63 S^0.54
(3) C = V / 1.318 R^0.63 S^0.54
(4) S^0.54 = V / 1.318 C R^0.63
(5) S = (V / 1.318 C R^0.63)^1.85
G.P.M. / 448.83 = C.F.S.
G.P.D. / 646.315 = C.F.S.
G.P.M. = 448.83 X C.F.S.
G.P.D. = 646.315 X C.F.S.
R^0.54
R^0.63
R — S
D. R. TAYLOR ROANOKE, VA.

Diagram and Formulas for Solving Flow Problems

or roots of numbers, and the decimal points are shown in each case. Furthermore, if all of this eventually leads to a complete comprehensive study of your entire distribution system, the purchase of an hydraulic slide rule (based on the Williams and Hazen formula) will be a good investment. With any great volume of hydraulic computations to be done, the answers can be rapidly determined with one of these rules, which is just as easy to use as the ordinary slide-rule.

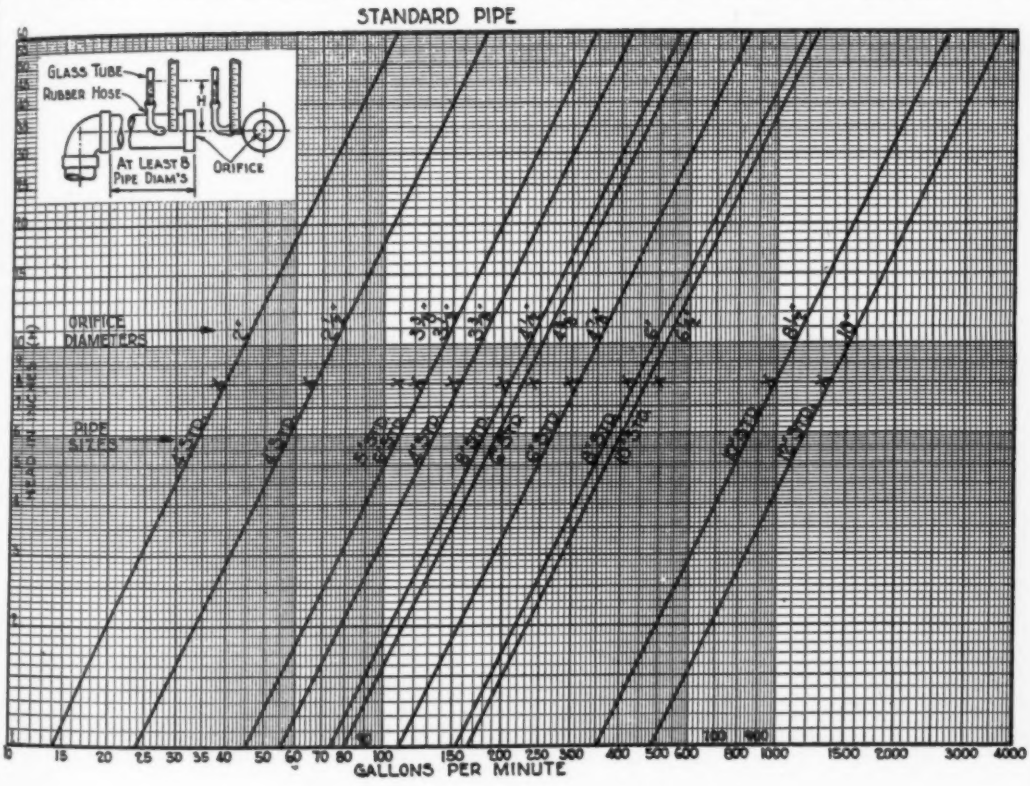
CAST IRON PIPE DIMENSIONS
and Hydraulic Radius Values

TABLE 1.

Nominal Diameter	Nominal Standard Dimensions All Cast Iron Pipe: Area Sq. Ft.	Diam. Feet	$R = \left(\frac{\text{Diam. Ft.}}{4}\right)$	$R^{.665}$	Actual Standard Dimensions Pit-Cast Class B: Unlined Area Sq. Ft.	Unlined Diam. Feet	Cement Lined Area Sq. Ft.	Cement Lined Diam. Feet	Super Delavaud Class 150: Unlined Area Sq. Ft.	Unlined Diam. Feet	Cement Lined Area Sq. Ft.	Cement Lined Diam. Feet
2"....	.0218	.1667	.0417	.135	.0218	.1667	.0192	.1562	.....	....	.....	....
3"....	.0491	.2500	.0625	.175	.0532	.2600	.0490	.2495	.0539	.262	.0495	.251
4"....	.0873	.3333	.0832	.209	.0915	.3418	.0825	.3240	.0920	.342	.082	.322
6"....	.1963	.5000	.1250	.270	.2060	.5120	.1890	.4900	.207	.513	.190	.492
8"....	.3491	.6667	.1665	.324	.3520	.6690	.3300	.6490	.367	.685	.346	.663
10"....	.5454	.8333	.2083	.372	.5420	.8300	.5150	.8100	.562	.8465	.536	.826
12"....	.7854	1.0000	.2500	.417	.7820	.9960	.7500	.9760	.812	1.016	.780	.996
14"....	1.069	1.1667	.2917	.460	1.065	1.1640	1.005	1.132	1.152	1.212	1.100	1.180
16"....	1.396	1.3333	.3330	.500	1.398	1.3320	1.332	1.302	1.500	1.382	1.440	1.352
18"....	1.768	1.5000	.3750	.539	1.768	1.5000	1.700	1.470	1.890	1.550	1.820	1.520
20"....	2.182	1.6667	.4167	.576	2.182	1.6670	2.100	1.635	2.340	1.725	2.250	1.692
24"....	3.142	2.0000	.5000	.647	3.142	2.0000	3.060	1.972	3.350	2.062	3.25	2.035
30"....	4.909	2.5000	.6250	.744	4.880	2.4950	4.720	2.451	....	....	....	....
36"....	7.069	3.0000	.7500	.834	7.080	3.0000	6.840	2.958	....	....	....	....

FLOW MEASUREMENTS WITH THE CIRCULAR ORIFICE AT END OF PIPE

(Peerless Pump Bul.)


STANDARD PIPE
GLASS TUBE
RUBBER HOSE
H
AT LEAST 8 PIPE DIAM'S
ORIFICE
ORIFICE DIAMETERS
PIPE SIZES
HEAD IN FEET
0 15 20 25 30 35 40 50 60 70 80 100 150 200 250 300 400 500 600 800 1000 1500 2000 3000 4000
GALLONS PER MINUTE

To obtain an accurate result in measuring the flow of water with a circular orifice the following conditions are to be maintained: Pipe must be horizontal with no elbows, obstructions or bends within 8 pipe diameters of discharge end; the orifice must be running full of water and "H" be at least one inch above top of the pipe.

Drill and tap discharge pipe on the side through center line for ⅛" pipe connection one foot back from orifice. It is very important that the ⅛" nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

When the rubber hose connection and the glass tube are installed "H" may be measured from the center of the pipe with an ordinary rule.

ELECTRICAL THAWING

of Service Lines and Small Mains

By FRANK C. AMSBARY, Jr.
Superintendent
Champaign, Illinois

THE following review of factors entering into the problem of thawing water service pipes is based upon the use of electrical energy derived either from transformers connected to convenient power lines, or the gasoline engine driven welders. These comments, suggestions and recommendations, being presented at the request of the editor of "Water Works and Sewerage," are based on long experience by the writer's company with electrical thawing methods.

Selecting a Transformer

In the selection of a transformer for this purpose, two classes of equipment are available. The small portable transformer which is connected to the house electrical service lines and transformers which must be connected to the power company lines on the poles.

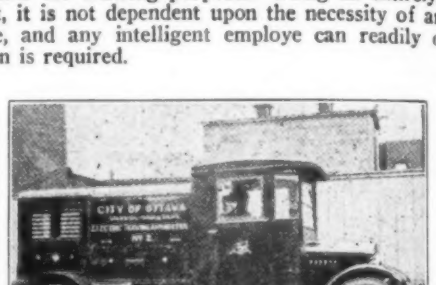
The small portable transformers with which we have had experience, due to the limited current carrying capacity of the electric service into the average residence, necessarily has a small output, resulting in limited applications and slow thawing. However, it is particularly suitable for thawing plumbing inside of structures or where only a short run of small pipe has been frozen, also for services of lead.

For all purpose use the transformer connected directly to the lines on the power company poles is usually the best. If this source of energy is chosen, suitable arrangements for the transformer, a lineman to make the primary connections, and a satisfactory energy charge can undoubtedly be made through the local office of the power company.

The power company should be cautioned to furnish a transformer with the *lowest voltage available on the secondary* to keep handling hazards at a minimum, and a current capacity of not over 200 amperes if the services to be thawed are of steel, wrought iron, lead, or cast iron, and not over 400 amperes if the services are of copper.

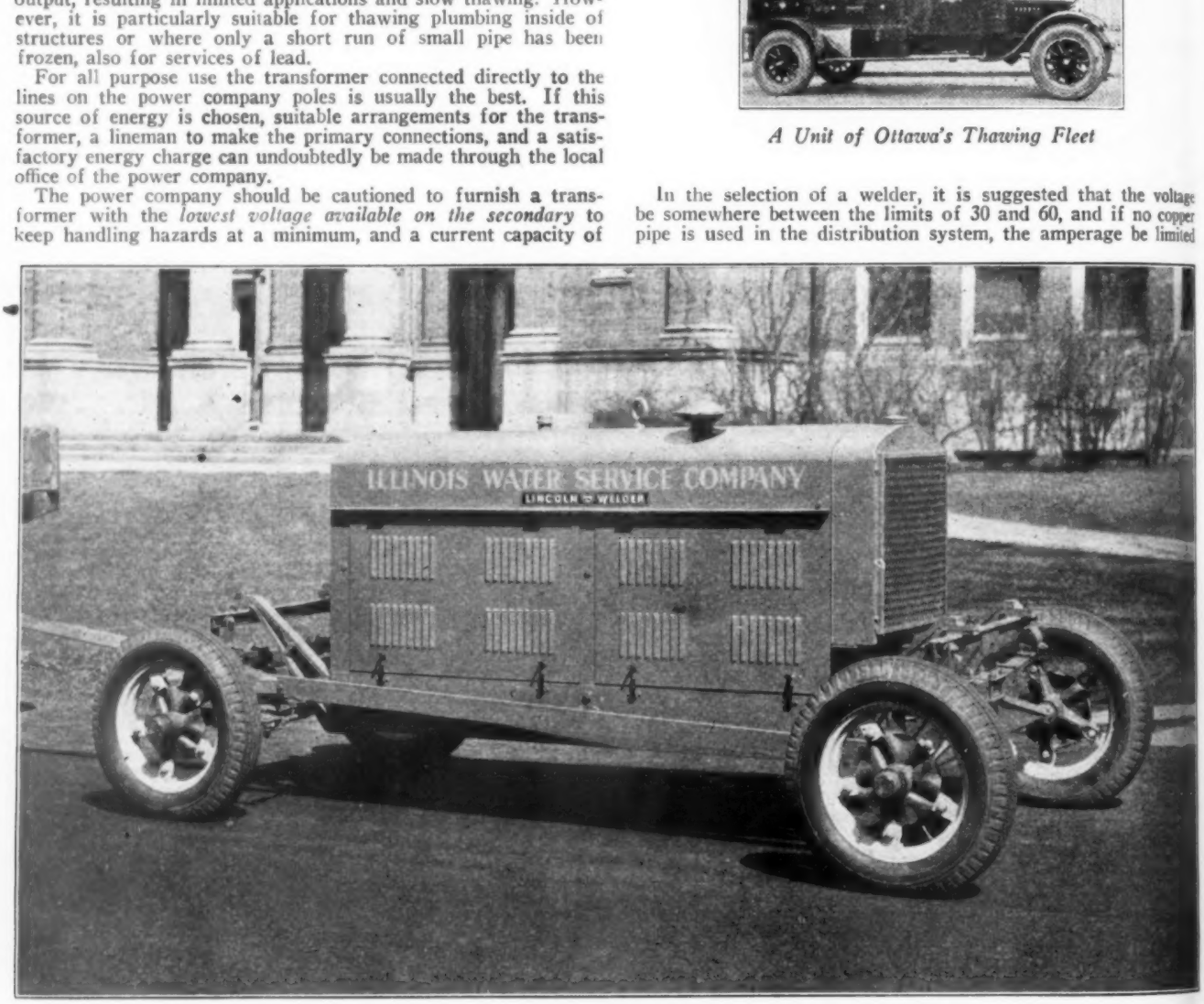
Welding Generator Units

The gasoline engine driven welder is probably the most flexible unit available for thawing purposes. Being an entirely self contained unit, it is not dependent upon the necessity of an adjacent power line, and any intelligent employe can readily operate it. No lineman is required.



A Unit of Ottawa's Thawing Fleet

In the selection of a welder, it is suggested that the voltage be somewhere between the limits of 30 and 60, and if no copper pipe is used in the distribution system, the amperage be limited



Our Combination Welder and Thawing Unit
Purchased for Thawing, and Use Also as a Welder. This Heavy Duty Unit Has an Output Range of 150 to 600 Amperes at 40 Volts.

to 200 amperes. If copper pipe is likely to be encountered, the upper limit should be 400 amperes.

There is a considerable difference between the cost of a 200 ampere and a 400 ampere welder, and this difference in cost cannot be justified if there is no need of the larger currents.

All welders are equipped with controls to regulate the amperage, which readily adapts even the 400 ampere welder to any of the service materials in common use.

Suggesting Current Rate for Various Materials

The following table showing the resistance and approximate melting points of the more common metals used in service lines, along with the suggested rate of current to be used for each, tells a comprehensive story of thawing in itself.

It is suggested that operators of the thawing equipment be furnished copies of this table to carry with them at all times, so each will be fully advised of the conditions that must meet on each job, by ready reference.

Metal	Ohms Per Milfoot*	Approximate Melting Point	Suggested Rate of Current
Copper	9.35	1900° F.	300 to 400 amps
Steel	63.00	2600° F.	200 amps
Wrought iron ..	82.80	2800° F.	200 amps
Lead	123.00	625° F.	75 to 150 amps
Cast iron	684.00	2500° F.	75 to 150 amps

*Resistance in piece of metal which is .001 inch in diameter and 1 foot long.

The smaller the value in ohms per milfoot, the higher the rate of current required to produce sufficient heat to melt the ice. For this reason the highest rates are recommended for copper. Due to the high resistance of lead and cast iron, lesser rates will accomplish the desired results in a reasonable time and *in all cases the smallest rates compatible with time* should be used to eliminate dangers always present when large currents are used.

The melting point of the metal of the more generally used materials found in service construction is included in the above table to suggest the danger of melting lead service pipes. It will be noted that lead, which has the lowest melting point, also ranks next to the highest in resistance. To prevent over-heating and melting of lead, the low rates must be used. It follows that the 75 to 150 amperes which is recommended for lead will thaw a service of this material in a reasonable period of time, while if this same rate is used on copper, due to its low resistance, the heat generated will be negligible.

Rates recommended for lead should be used where lead goosenecks are used regardless of the material used in the balance of the service. Lead joints in cast iron pipe must likewise be protected by the use of small rates.

Time Required Depends Upon Current

The period of time required to thaw a service is inversely proportional to the *square* of the current. For example, with a one-half inch service, if it requires 10 minutes to thaw at 200 amperes, it will require 40 minutes at 100 amperes.

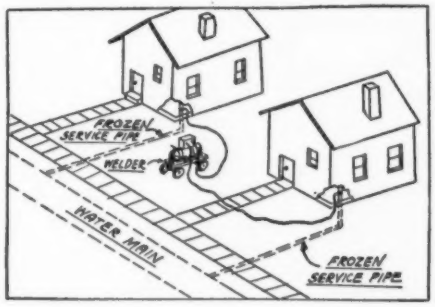
Regardless of the number of services waiting to be thawed, *time should be secondary to safety;* and, for safety, the rates recommended in the table should not be exceeded.

Wire Size Important Also

The following table gives safe current carrying capacity for the leads from the source of energy to the pipe to be thawed. It is assumed that the length of such lead wires will be kept at a minimum.

Size Wire B & S	Safe Current Carrying Capacity*
O	200 amps
OO	225 amps
OOO	275 amps
OOOO	325 amps

*For short periods of thawing twice these rates of flow may be safely employed.

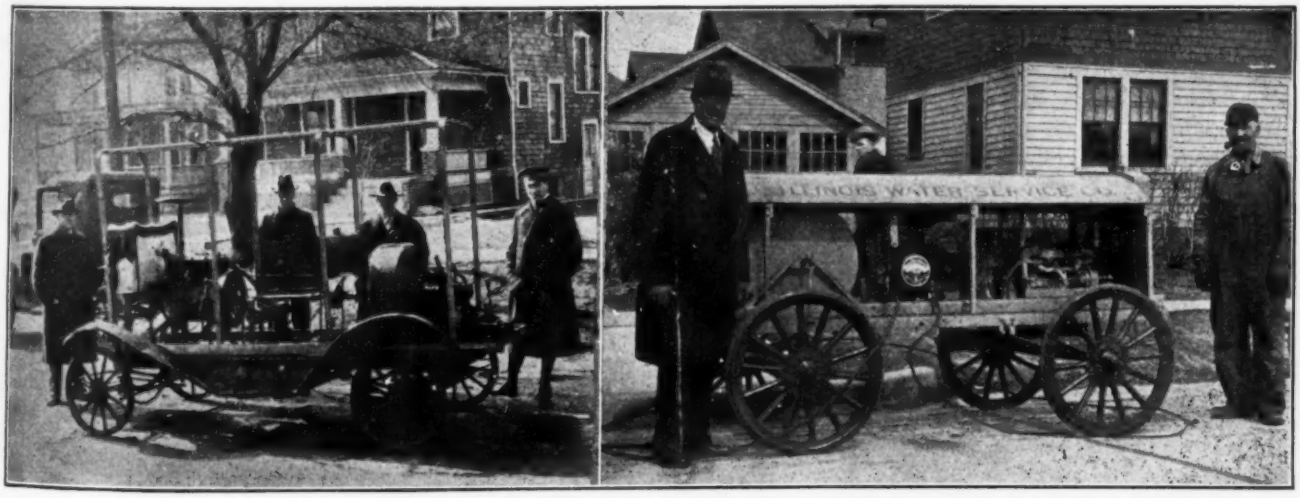


Suggested Thawing Hook-Up
By This Arrangement Two Services Can Be Thawed at One Operation. If Only One Service Is to Be Thawed, One Wire (Either One) May Be Connected to a Fire Plug. Before Turning on the Current It Is Important to Disconnect the House Piping From the Service Lines.

Procedure and Precautions:

The following example for thawing a frozen service is based upon the assumption that meters are set in the basement, and the thawing circuit is closed by connecting one wire from the source of energy to the frozen service pipe in the basement and the other wire to the service pipe in the adjacent house (see sketch); also that a good quality C clamp, or similar appliance for making the electrical contact to the pipe, is used. It is recommended that a solderless lug be clamped on the end of the wire and then securely bolted to the C clamp.

First remove the meter in each basement or in some way break all connection between the house piping and the line to be thawed. Remember that in thawing services one is dealing with a current that in some cases is as high as 40 times the average lighting demand of a home. Due to grounding of house lighting circuits



1918—*Other Equipment We Have Known*—1929
(Both Being Put Together in Our Own Shop)

to water pipes, if the meters are not removed, or some other break made in the line, the current used in thawing the service may feed back into the light circuit and cause serious damage. Houses have been burned down due to such a condition. Another source of feed-back is through the water heater to the gas line, which may melt the lead gaskets in the gas meter.

Special care should be exercised to see that all rust, scale, grease, etc., is removed from the pipe at the point where the C clamp is fastened to the pipe. Unless a good contact is made, arcing is likely, which may cut holes completely through the pipe. Poor connections also waste electrical energy and slow up thawing.

The connections now having been made to both services, thawing may be started. Do not make the common mistake that has caused trouble by assuming the removal of the meters will eliminate all sources of feed-back from the thawing circuit. Water pipes may make contact underground with the gas distribution system and thus feed-back into the house. During the entire period of thawing constant check on the gas pipes in both houses should be made, as well as to adjacent properties that are entirely out of the circuit established for thawing. Lead gaskets in gas meters have been melted out in the basements of homes not included in the thawing circuit. Continually check connections and joints in the circuit to see that they are not overheating.

Some Final "Dos and Don'ts"

(1) Use the smallest current possible to accomplish the job; do not hurry by using large currents.
(2) Be sure of good electrical contact from source of energy.
(3) Be sure your wires from the source of energy are adequate.
(4) Be sure that you know the material used in the service and adjust the current used accordingly.
(5) Be sure to check for any feed back of the current used in thawing through the gas service. Any heat detected by placing the hand on the gas meter couplings will immediately indicate such a condition.

Polarity does not really make much, if any, difference in the efficiency of the circuit.

But—NEVER FORGET THAT IN THE USE OF LARGE CURRENTS IT ALWAYS PAYS TO BE CAUTIOUS!

RAPID EMERGENCY METHOD OF THAWING HYDRANTS*

By E. E. JACOBSON

Chief Engineer, Lexington Water Co., Lexington, Ky.

One of the many worries of the water works man during the cold winter months is the problem of fire hydrant maintenance and their operation when the thermometer drops below freezing.

Proper inspection and drainage of fire hydrants will eliminate most of the trouble, but hydrants only a few days after inspection have been found to contain water in the barrel. As the weather turns cold the water in the barrel becomes ice and the hydrant will not operate. No doubt every water works superintendent in states that have cold winters has experienced frozen fire hydrants.

The method used in Lexington, Ky., for a number of years as an emergency method of thawing ice from hydrant barrels is by pouring concentrated sulphuric acid into the hydrant barrel. During the Fall each piece of apparatus of the Lexington Fire Department is supplied with a quart bottle of sulphuric acid (66% commercial). When the acid is used the Lexington Water Company is notified and another bottle is sent to the fire station. In the Spring of the year these bottles are collected and fresh acid is issued each Fall.

When answering an alarm and a hydrant is found to be frozen, the acid is poured into the barrel through the nozzle and a slight pressure put on the stem operating wrench. As soon as the heat produced by the acid drills a hole through the ice cake the hydrant is opened, flushing out the acid with the first gush of water.

In frozen hydrants we have found that the ice forms first above the valve and in most cases it is doubtful if the acid reaches the valve because the stem turns and the water is turned on as soon as the ice melts around the stem.

The average time for thawing hydrants with acid is about three minutes although this would depend upon the thickness of ice in the barrel of the hydrant, and might vary considerably from the above time if very thick.

The advantages from this method of thawing hydrants comprise the ease of handling the thawing material on the fire trucks, the small space necessary on the trucks, simple to use, inexpensive, and the rapidity of results. Hydrants in which acid was used have been taken apart and no ill effects to the hydrant parts could be found.

The effectiveness in the use of sulphuric acid for this purpose can be determined by the following letter from the Chief of the Lexington Fire Department:

Mr. E. E. Jacobson, Chief Engineer
Lexington Water Company,
Lexington, Kentucky.
Dear Mr. Jacobson:

Relative to our conversation this morning, I am furnishing you with all the information that I have in regards to the use of sulphuric acid in thawing fire hydrants during extreme cold weather.

In case a hydrant is found to be frozen, one of the caps of the hydrant is removed and a quart of acid is dumped into the barrel of the hydrant. The suction hose is then replaced on the hydrant, and in the majority of the cases the hydrant is thawed out by the time the suction is replaced, and the hydrant is turned on. The water and acid is allowed to flush out through the pumper or the hose, and we have found that little or no damage is caused by this action, due to the fact that the acid is neutralized by water to such a degree that it is harmless to the pumper or the hose.

In some instances the acid is a little slow about thawing the hydrant, but in these cases it is usually in certain parts of the city, where the surface water seeps in the barrel of the hydrant, causing the hydrant to have more water than usual in the barrel, but as soon as these hydrants are found, your company has had them filled with alcohol, thereby eliminating this trouble.

You will notice that we say that we replace the suction on the hose to the hydrant before we turn on the water. This is done to prevent acid burns to members of the department and the hose and apparatus that is near the hydrant. The first spurt of acid and water from the hydrant would be dangerous to anything that it touched, but by replacing the cap, the acid is diluted with the water to a point where it is practically harmless to anything it might touch.

It has required from two to eight minutes to thaw a hydrant with acid, where it usually requires about ten minutes to thaw out a hydrant with a regular thawing device, old style thawing device.

A test was made at fire department headquarters today. A fifty pound block of ice was used and one quart of sulphuric acid was poured into a hole in the ice. Ten minutes later a hole was burned in the ice eight inches deep, six inches wide and ten inches long. Of course, this was a little longer than it would have been in a hydrant, due to the fact that acid will follow the stem of the hydrant and penetrate into the ice faster than it did during the test. We have found the use of sulphuric acid for thawing hydrants to be most satisfactory.

C. J. HENRY,
Chief, Lexington Fire Department.

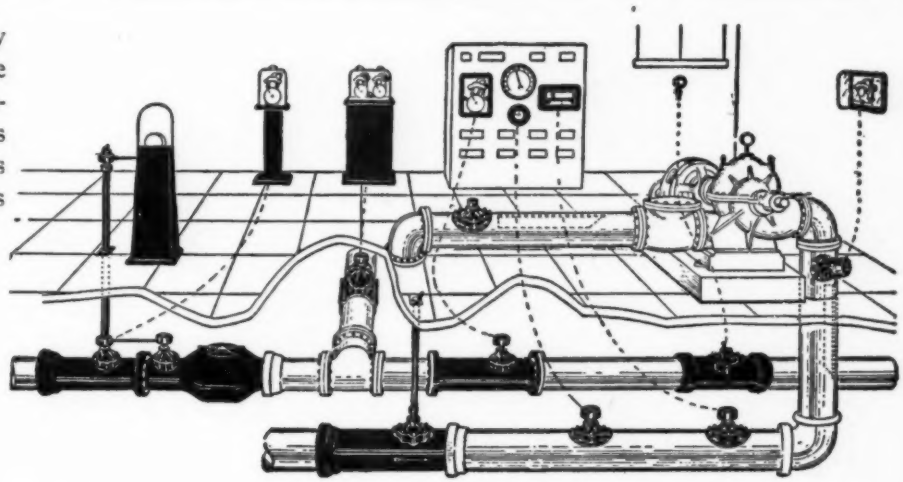
R. W. SPARLING

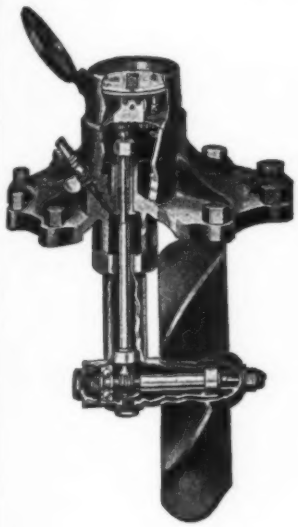
MANUFACTURER OF

MAIN-LINE WATER MEASURING EQUIPMENT

Box 3277, Terminal Annex, LOS ANGELES 54 — 3104 S. Michigan Avenue, CHICAGO 16
622 Broadway, CINCINNATI 2 — 101 Park Avenue, NEW YORK 17 — 6 Beacon Street, BOSTON 8

TOTALIZATION is the primary step in all Sparling Main-Line Meters. Flow-rate indicators, recorders and controls are added as desired. Accuracy at rated range is guaranteed within 2 per cent and loss of head pressure is negligible.





Note Direct Action from propeller to totalizer, which registers in quantity unit desired. Sparling Meters may be installed on suction or discharge side of pump, in horizontal or vertical position. The meterhead may be saddle-mounted on the pipe or installed as a tube section. See above for suggested installations.

A complete totalizing unit can be installed in a 6-inch pipe for $240. Tube-mounted meters, with liners and straightening vanes cost slightly more. The complete line of standard Sparling Meters is covered in Bulletin 308, sent upon request, and is the result of 26 years' experience with the propeller type main-line meter.

FLANGED TUBES
2-inch to 36-inch

•

SCREW TUBES
2-inch to 6-inch

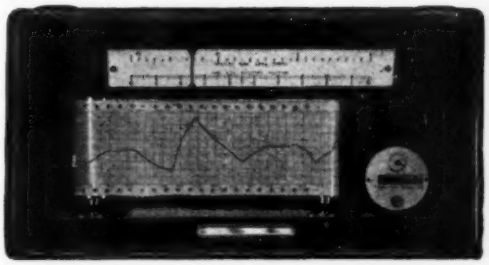
•

BELL & SPIGOT TUBES
4-inch to 36-inch

•

SADDLE MOUNTED
6-inch to 72-inch
For Iron, Steel, Wood, Concrete and Transite Mains

INDICATORS • RECORDERS

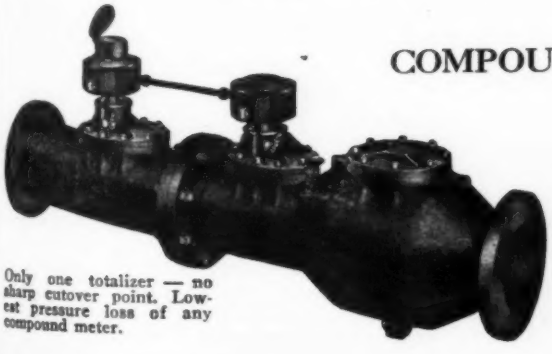


Flow-rate indicators and recorders are available for use with Sparling Meters if, as and when required. The mercury-governor type, with circular charts for 24-hour or 7-day records, are mechanically controlled within 15 feet of the meter, or electrically controlled at any distance. They may be Pedestal, Wall or Panel mounted.

Also the differential type, shown above, with straight-reading 60-day strip roll chart. Indicator scale is calibrated in two flow equivalents. Operated by electric remote control.

Mechanical or electric controls for auto-metered sampling or chemical feed are available.

Bulletin 308 *is sent upon request.*



Only one totalizer — no sharp cutover point. Lowest pressure loss of any compound meter.

COMPOUNDS for Mains Up to 36-inch

Sparling Compound Meters are available with flanged or bell and spigot ends for main lines from 6-inch to 36-inch. Flow-ranges as wide as 1 to 125 are accurately registered.

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York 16, N. Y.

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TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

TRANSITE PRESSURE PIPE . . . *a brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—*

12 WATER PIPE PROBLEMS AND HOW TRANSITE PIPE HELPS SOLVE THEM

●

TRENCHING COSTS

Trenching costs are low with Transite. No bell holes are required at the joints, and the width of trenches and disturbance to pavement are kept to a minimum.

HANDLING COSTS

Transite's light weight means more footage per truck load—easier handling at the trench.

INSTALLATION COSTS

Fast assembly with the Simplex Couplings keeps installation costs low, minimizes traffic tie-ups.

CURVES

Transite's flexible Simplex Couplings permit deflections up to 5° at each joint without use of fittings.

JOINT LEAKAGE

Tight, flexible Simplex Couplings guard against costly underground leakage and washing away of supporting soil and undermining of the pipe.

RED WATER

Made of asbestos and cement, Transite Pipe cannot rust—cannot cause red water.

ELECTROLYSIS

Stray electric currents from power lines cannot damage this non-metallic pipe.

VIBRATION

Transite's flexible joints absorb the vibration of heavy traffic—stay tight in service.

SOIL STRESSES

Major factors assuring high resistance to soil stresses are Transite's high uniform strength, its exceptional resistance to corrosion, and tight Simplex Couplings.

SOIL CORROSION

Hundreds of installations in aggressive soils prove Transite's high corrosion resistance.

DELIVERY CAPACITY

Tuberculation cannot reduce Transite's high delivery capacity (C = 140). Therefore, pumping costs stay low.

MAINTENANCE

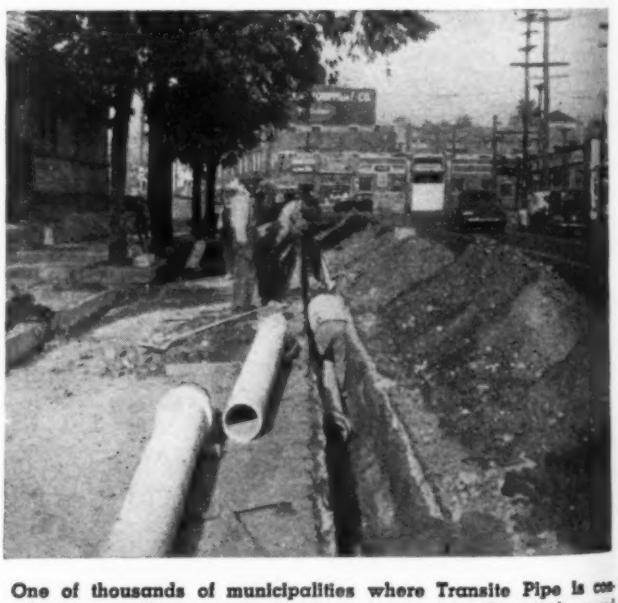
Because of its corrosion resistance and tight joints, maintenance costs are kept low.

IN SELECTING a pipe for water lines—whether for the extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

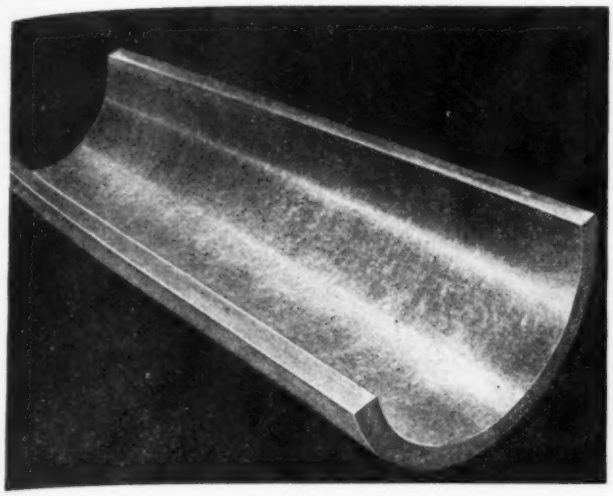
Waterworks engineers generally agree that a water main, even though it remain structurally intact, may outlive its economic usefulness over a period of time. This points is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand on its delivery capacity, or from a combination of these two causes. Therefore, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for larger sizes of pipe than would otherwise be necessary. However, there is another, more



One of thousands of municipalities where Transite Pipe is contributing to efficent, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.

JOHNS-MANVILLE



The smooth interior surface of Transite Pipe provides an exceptionally high delivery capacity (C = 140). Transite's high flow capacity and low pumping costs are not subject to tuberculation.

Over 62,000 feet of 10-inch to 30-inch Transite Pipe were used on this water collection and transmission system. Because of its light weight and speed of assembly, the pipe was laid as fast as the trench was opened.

fundamentally sound solution. In J-M Transite Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will never be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces carrying capacity.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively established at C = 140, which provides an exceptionally high carrying capacity.

Transite's freedom from tuberculation means that pressures need not be increased, mains periodically cleaned or systems reinforced with larger or additional mains to compensate for a steadily decreasing flow coefficient arising from this costly form of internal corrosion. Furthermore, in many cases Transite Pipe permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of a completed water line.

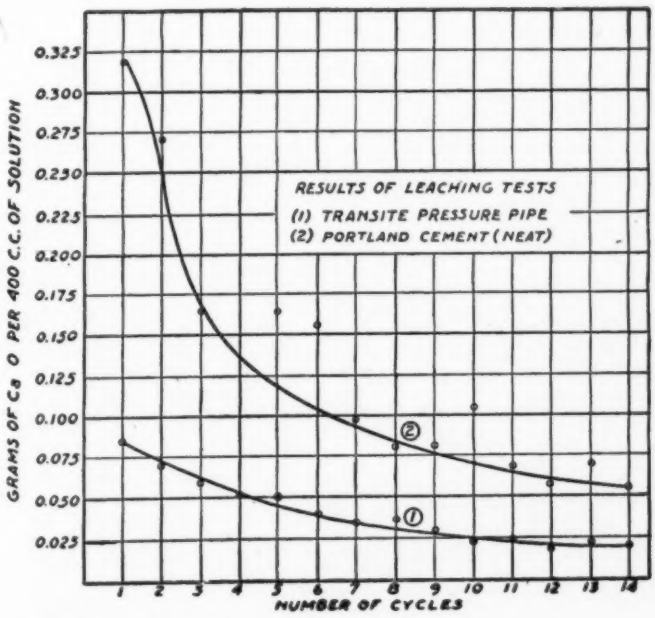
SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electro-chemical.

Chemical corrosion is caused by the direct, corrosive action of acids and salts encountered in the soil. Transite Pipe, due to a special process of manufacture and treatment, is virtually inert to concentrations of acids and salts ordinarily found in soils. Free lime which might generally be expected in cement products, has been largely converted to insoluble silicates due to the method of manufacture. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so resistant to the forms of chemical corrosion as encountered in soils.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and substances in the soil. This action is similar to that of a simple electric cell. In this case, the substances in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the pipe to the positive pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

JOHNS-MANVILLE

occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrochemical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric currents from high voltage lines, street railways, etc.

The successful performance of thousands of Transite Pipe installations in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside, and all the way through.

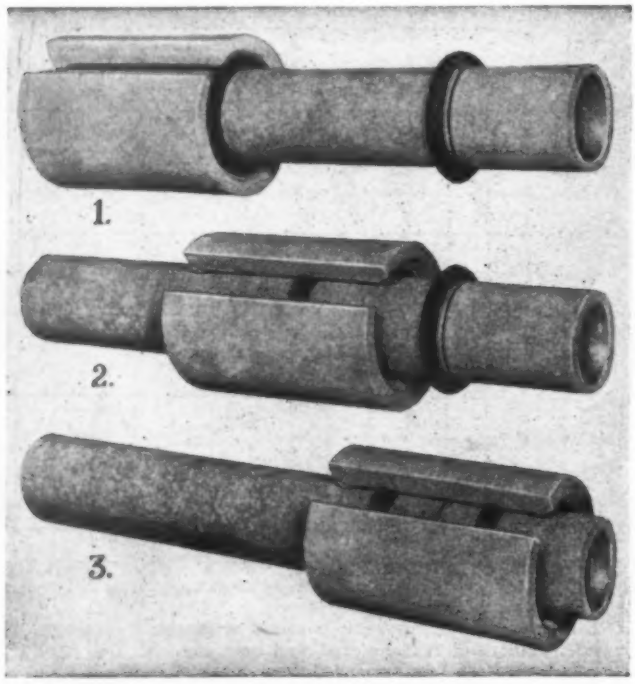
JOINT LEAKAGE . . .

Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water, but, by washing away supporting soil, contributes to failure of lines under traffic and earth loads.

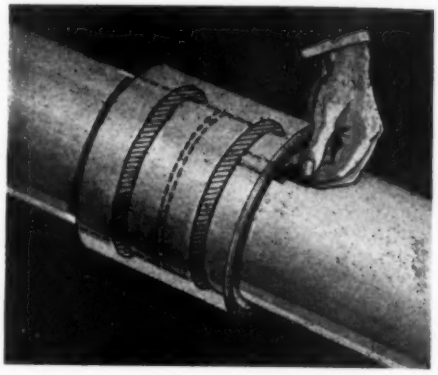
Much of this trouble is caused by the fact that the ordinary rigid joint, even though initially tight, may open up when subjected to vibration or settlement after the line is in service.

Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility guards against vibration and stresses transmitted by the soil. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

The ease of assembling the Simplex Coupling and its dependability in service is due primarily to these distinctive features:



Simplex Coupling Assembly. (1) at start of operation, (2) sleeve pulled over one ring, (3) final position, sleeve centered over joint.



With Simplex Couplings tightness of the joint can be determined from the outside as soon as the pipe is laid. A thin steel blade, slipped under the lip of the sleeve, checks the position of the rubber ring. If the position is right, the joint is tight.

1. It is actually a pre-fabricated, "packaged" joint. The ends of each pipe and the inside of each coupling are machined to specific dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is used. A simple coupling puller, loaned by Johns-Manville without charge, is the only tool required for assembly.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service. Thousands of installations testify to their dependability and permanence.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact, all but the largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem. Assembly of the line is completed with savings in time and man hours of labor expended.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For your free copy of these books write to Johns-Manville, Box 290, New York 16, N. Y.

JOHNS-MANVILLE

IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Transite Sewer Pipe offers fundamental advantages that help reduce the cost of sewer line construction, maintenance and operation.

TRANSITE SEWER PIPE

Gravity Sewer Lines offer a number of specialized problems which Transite Sewer Pipe meets eminently well. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself, thereby increasing operating costs and hastening the day when plant facilities may have to be expanded to provide for increased load resulting from a normal population growth. Furthermore, in many cases engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. Furthermore, the sleeve type joints employed in Transite lines are unusually tight and stay tight in service. The joint is strong, flexible and highly resistant to cracking or shrinkage stresses. As a result, Transite Sewer Pipe installations have shown far less infiltration than that allowed by the usual specifications.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficients. If, for example, the inside of the pipe is rough and uneven, the flow velocity and carrying capacity are greatly reduced. A smooth pipe provides a higher flow velocity and a correspondingly higher carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient being $n = .010$. The resulting high carrying capacity means savings that can be taken in one of two ways. Flatter grades may be employed during installation—reducing the depth of the trench, and therefore cutting down on the amount of excavation required, and making installation a faster, more economical job. Or, when a steeper sewer pipe grade is employed and deeper trenches excavated, Transite's higher flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize inflation.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength, and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its special asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of domestic sewage and most industrial wastes—inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4″ to 36″ in Class I, from 10″ to 36″ in Classes II and III, and from 18″ to 36″ in Class IV. Each class of pipe is made to specific crushing strengths, thereby providing for the selection of the most economical combination of classes of pipe to meet the specific strength requirements of the line and eliminating the need for concrete cradling.

The long 13-ft. sections in which Transite is furnished eliminates many of the problems encountered in the installation of short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer man-hours of labor are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe and maintaining the line to an accurate grade.

TRANSITE PRESSURE PIPE FOR SEWER LINES

Operational requirements of pressure sewer lines are very similar to those of water lines. In addition, the pipe must be resistant to the corrosive action of the sewage. Transite Pressure Pipe for sewer lines, which is made of the same durable asbestos-cement composition as Transite Water Pipe, described on the preceding pages, meets all these requirements and provides highly satisfactory service in systems of this type as demonstrated in numerous installations.

For further details on Transite Sewer Pipe for gravity lines, write Johns-Manville, 22 East 40th St., New York 16, N. Y., for Brochure TR-21A; on Transite Pressure Pipe for force mains, write for TR-11A.

DE-WATERING MAINS WITH COMPRESSED AIR

Eliminates Pumping, Wet Trench, Loss of Time

By ARTHUR C. KING
Superintendent of Water Works, Taunton, Mass.

IN THE 1939 Reference Data Issue of "WATER WORKS AND SEWERAGE" an article by Roger W. Esty and Nelson Boardman of Danvers, Mass., describes the use of compressed air for removing water from mains.

Here in Taunton, Mass., we have adopted the method, developed by Esty and Boardman, and have successfully used it on pipe of such size that we believe our experience might be of interest to others who may have questioned the value of the scheme for mains of larger sizes. (See sketches on next page.)

An Experience with a 12-Inch Main

It became necessary to relocate about 600 feet of 12" cast iron main. Since occupied buildings were supplied from the section to be relocated, it was decided to lay the new main before cutting off the old for salvage.

After the new pipe was laid, the problem was that of making the connections between the old and new as quickly as possible, both on account of regular use and also the reduction in fire protection during the change-over. The section to be drained (about 2500 ft.), lay on an up-grade, as will be seen on the accompanying sketch (a), and hydrants were already in place at the high end and near the low end. The main was shut down, the hydrant near the low end was opened, and the air compressor connected to the hydrant *at the high end.* In a surprisingly short time, perhaps 40 minutes, although it was not timed, water ceased to come out of the hydrant and the main was cut. No water came out through the cut. The old and new sections were connected and the water turned into part of the new main within 4 hours, restoring service to all buildings. The upper end was then cut off and reconnected. Not a bit of ditch pumping was required.

We Try a 16-inch Main

Another large main de-watered with compressed air was of 16" cast iron. The length between gates was about 1200 feet—see sketch (b). About 800 feet was on a slight up-grade to a summit, where there was a hydrant. The other 400 feet was on a downgrade to the point of cutting, with a hydrant in that shut-down section just beyond the cut. The low hydrant was opened and the compressor connected to the hydrant at the summit. The water was quickly driven out and the cut made. In this case, apparently some gate was not shut quite tight as a trickle of water occasionally came out, but it was not enough to make trouble for us. We considered this job also a remarkable demonstration of the Danvers method.

On second thought, another hydrant might have been opened to de-water part of the main on the slope back from the summit away from the work, before the cut was made. Then the leakage would have accumulated back of the summit.

We Do a 20-inch Job

On another occasion we used the air to empty about 700 feet of 20" cast iron pipe, sketch (c). The upper end was nearly level for about 200 feet then the pipe sloped down from a hydrant at the summit about 500 feet past the work to be done to a hydrant at the low end. Here again no difficulty was experienced and the water was driven out very quickly, but was not timed.

We also drained about 1200 feet of 12" cast iron shown on sketch (d). In this case we cut out and replaced an 8" gate valve on a branch main a few feet away, and on an up-grade, from the 12" main. The whole job of de-watering, cutting out the old and inserting the new gate, was completed in less than 2 hours.

Our compressor is set for a maximum of 95 pounds pressure and starts up when the pressure drops about 10 pounds. We did not note what pressure was held during de-watering, but there was no indication of lack of air or pressure for these lengths of 12", 16" and 20" mains. The rated capacity of our compressor is 110 cubic feet per minute.

The scheme proved its worth very effectively.

IMPROVED METHOD OF MAKING WET TAPS

By E. T. CRANCH
Manager, New Rochelle (N. Y.) Water Co.

It is assumed that all waterworks men are familiar with the ordinary hand operated machines for the making of wet-taps.

The hand operated machine, while a great convenience was, however, tedious to operate. A six or eight inch tap would take two or three hours to cut and the larger taps much longer. It would also take not less than three men, working in relays, to operate the machine successfully.

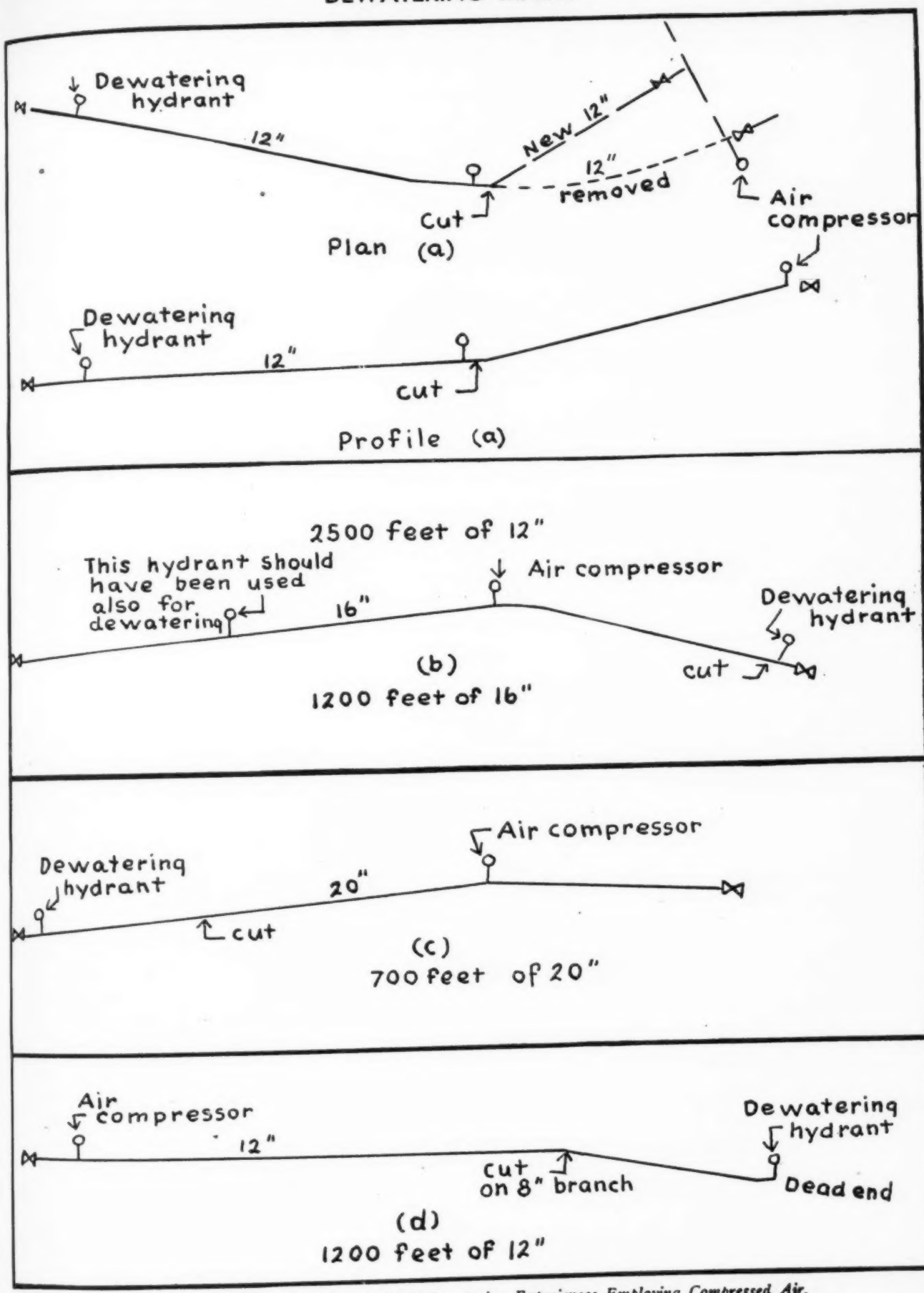
For plants which carry an air compressor unit in their equipment, there is now a means for making these taps quickly and easily. The old hand-type machine can be readily equipped with a bracket to permit the use of a compressed air motor and with a three-horse air motor an eight inch tap can be made in less than half an hour. With this arrangement it is also possible for one man to operate both the motor and the drill feed.

Equipping the machine with the motor-drive does not interfere with its continued use as a hand machine whenever conditions warrant, or should compressed air not be available at some time. It is only necessary to unscrew four stud bolts and remove the motor bracket. The machine is then ready for hand operation as before.

With the use of the air operated tapping machine we have recently made an 8-inch connection to a 12-inch main of class "B" pipe. In timing the whole operation it took just 90 minutes from the time the men started to place the sleeve on the pipe until the job was completed and the machine removed. The actual drilling time was, in this case, only 11 minutes.

The accompanying illustration is a picture made on an earlier job. The tapping machine, which is not new, was purchased some years ago from the A. P. Smith Mfg. Co. The compressed-air motor was supplied by Ingersoll-Rand Co.

DEWATERING MAINS



Sketches Revealing Conditions in Main-Dewatering Experiences Employing Compressed Air.

THE NATIONAL WATER MAIN CLEANING COMPANY

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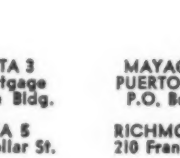


Before Cleaning

The NATIONAL METHOD

After Cleaning

30" Main in a Midwest City Before Cleaning

Our experts can make valuable suggestions about the best, quickest, and most economical ways to restore 95% of your pipe's original capacity.

WHAT YOU GAIN FROM MAIN - CLEANING by NATIONAL

1.—More Water

2.—Better Water

3.—Higher Pressures

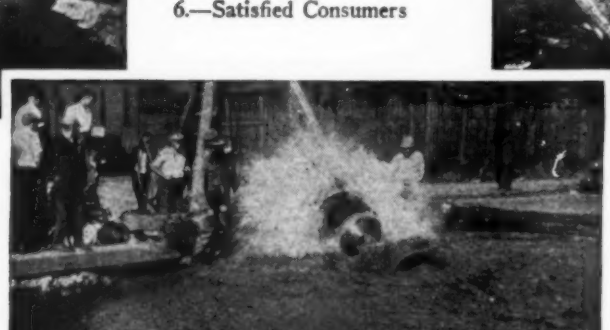
4.—Lower Pumping Costs

5.—Lower Fire Insurance Rates

6.—Satisfied Consumers

When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable

To put your water distribution system into first class condition for maximum service get in touch with our nearest office.



Machine Arrives at End of Run After Cleaning 30" Main in St. Louis

THE ONE place you want experienced service is in your water main cleaning. Too much depends upon your uninterrupted water supply to justify taking chances. 38 years of successful cleaning experience are at your command when you employ National to do this important work. All the improved technique that comes from being America's leading water main cleaners for over a third of a century is at your disposal.

Mains down over 20 years easily can lose 50% of original capacity through encrustations and foreign matters, which reduce pressure, quantity and quality of water, as well as increasing pumping costs and keeping insurance rates up. Such mains can be cleaned the National way in from 5 to 7 hours, at night if necessary. Service can be resumed very quickly in any emergency.

Information regarding any of the hundreds of successful cleaning projects will be supplied upon request.

GUARANTEED TO RESTORE 95% ORIGINAL CAPACITY

UPRATING DISTRIBUTION SYSTEMS BY CLEANING AND CEMENT LINING

By J. A. FRANK
Engineer, National Water Main Cleaning Co., New York, N. Y.

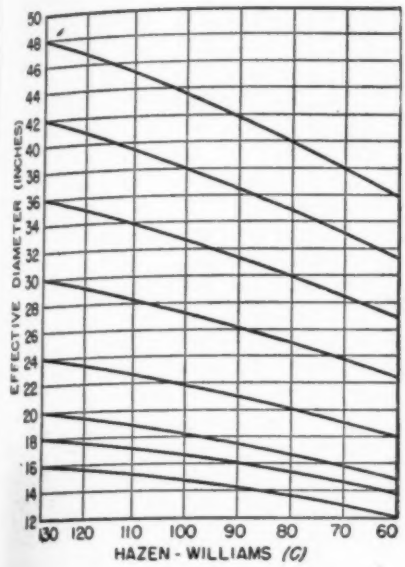


Fig. 1—Curves Revealing Loss of Effective Pipe Diameter as Tuberculation Increases —Likewise Recovery of Line Capacity Through Main Cleaning.

BECAUSE wartime restrictions on men and material made the laying of new mains extremely difficult, the rehabilitation of distribution systems by cleaning and lining is being practiced as the least expensive and quickest method of obtaining additional capacity. In so doing the useful life of the rehabilitated main is extended many years and the recovered capacity is assured of being sustained therewith.

There are many improved practices in both cleaning and cement lining and, with proper scheduling, work can be done much more quickly than in earlier years.

Some Modern Practices

The cutting of cast-iron pipe has long been a laborious, tricky and uncertain job and there is a decided trend toward the use of machines for this work. In the smaller pipe the use of a wheel-type cutter has been standard practice but, unfortunately, it cannot be used with any degree of satisfaction in sizes over 10 in. There are a number of methods which have come into use in the last few years for cutting the larger sizes of cast-iron pipe. The first of these methods utilizes a split machine which is clamped around the pipe. One or more tool bits of the partingtool type travel around the pipe, cutting the metal with a straight even cut.

The second method utilizes a pipe-cutting machine which travels around the pipe on a track of chain. The power unit, which is either an air or an electric motor, is connected through a gear box to a rotary saw which travels around the pipe, removing the metal with a straight even cut.

The third method utilizes the electric arc-welding machine, which produces good cutting results by the use of a negative polarity rod in straight polarity. It is necessary to have a high output machine and a special technic is required of the welder handling the electrode. Under proper conditions this method can be very rapid and result in an even true cut.

The development and utilization of these three methods of cutting have resulted in speeding up the work of cleaning, and the even cuts made possible by them permit the use of the nipples taken out of the pipe, thus reducing costs for material on the job.

The installation of the pipe cleaning tool into the main has long been a laborious and time-consuming job. In recent years, methods have been developed for inserting the cleaning tool so that comparatively it now takes only a few minutes.

Present-day pipeline fittings serve as another means of speeding up cleaning. By the use of mechanical-type couplings, such as Dresser, Skinner or Simplex, coupling up of the pipe after the cleaning machine has been inserted now requires only a few minutes, as compared with the practice of yesteryear which sometimes consumed hours.

Another factor in speeding up the cleaning process has been the accumulation and compilation of data on the required flow and pressure to propel the cleaning machine at the most effective speed of travel through the line. It is now possible to predict with reasonable certainty what pressures and quantities of water are going to be required to propel the machine and the approximate speed at which it will travel. With this knowledge, the work can be scheduled and laid out so that many former uncertainties no longer exist.

One of the most recent developments in connection with water main cleaning is the use of the two-way radio for communicating from point to point and controlling the job. In the cleaning of large mains in distribution systems we are faced with the problem of the disposal of large quantities of pipe cleaning water in heavily populated districts. The use of the two-way radio insures shut-offs before any damage can be done in the event of any failure of facilities to carry off the water.

Some Graphic Comparisons of Main Conditions

Figures 1 and 2 constitute curves which illustrate the effect of the roughness of pipe interiors on carrying capacity. Some average coefficient for new pipe had to be assumed and in these curves the Hazen-Williams C value of 130 has been assumed for pipe 16 to 48 in. in diameter, and 120 for smaller diameters.

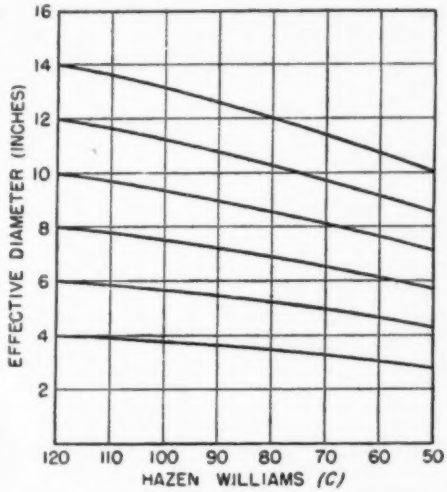


Fig. 2—Curves Revealing Loss of Effective Pipe Diameter as Tuberculation Increases —Likewise Recovery of Line Capacity Through Main Cleaning.

Figure 1 covers pipe in the sizes from 16 to 48 in. To read the uprating of a pipeline by cleaning, note that a 48-in. line with a coefficient as high as 115 has an effective diameter of 46 in. only. That 2 in. diameter loss represents a sizeable nonyielding investment in the 48-in. pipe that has but 46-in. service value. In this size pipe, cleaning would restore the main to 130 and the effective diameter to 48 in.

Figure 2 covers pipe from 4 to 14 in. diameter. A 14-in. pipe with coefficient of 80 would have an effective diameter of 12 in. only. In carrying capacity the loss is considerably greater, however, than the 14.3 per cent loss in effective diameter. By cleaning, this effective diameter can be increased to 14 in.

As an example of successful restoration of an old line to satisfactory carrying capacity, a record of operation in Trenton, N. J., will be reviewed.

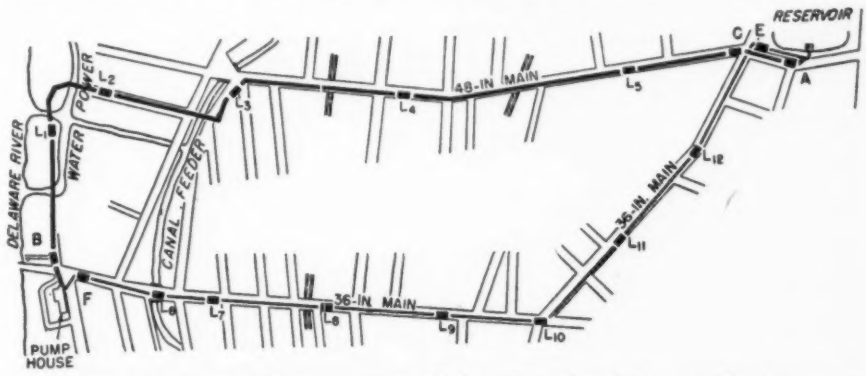


Fig. 3.—Plan of Trenton, N. J., Mains Cleaned and Cement Lined. (Stations of entry and egress of cleaning machine and lining apparatus are indicated.)

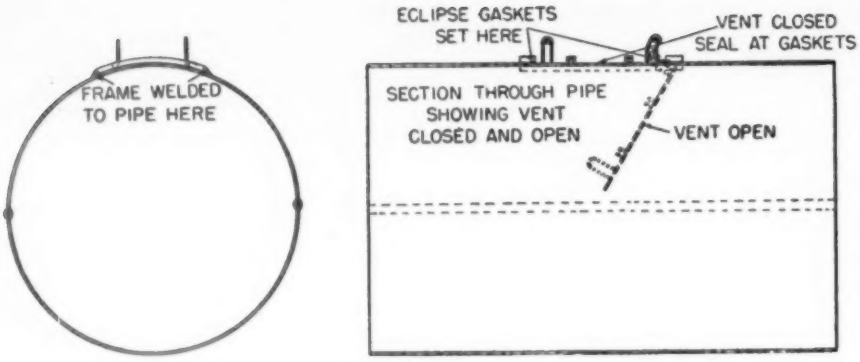

ECLIPSE GASKETS SET HERE
VENT CLOSED SEAL AT GASKETS
FRAME WELDED TO PIPE HERE
SECTION THROUGH PIPE SHOWING VENT CLOSED AND OPEN
VENT OPEN

Fig. 4—Automatic Air Vents Installed on Trenton Steel Mains.

Main Rehabilitation in New Jersey

Water for the city of Trenton is obtained from the Delaware River. An intake, built out into the river, supplies water to the suction side of low-lift pumps, whence it is pumped to the filter plant and there treated. The treated water flows by gravity to the suction side of high-lift pumps and is then carried through two ascending mains to the service reservoir which has a capacity of approximately 60 mil. gal. One of these ascending mains is a 48-in. lock-bar laid in 1907. The other ascending main is a 36-in. cast-iron bell-and-spigot laid in 1870. Figure 3 shows the plan of these two lines.

During the summer of 1940 it was decided to appraise these lines, determine their condition and lay out a suitable plan to insure their life. Since the lock-bar line was made of plate only 5/16 in. thick and, because access manholes were available, it was decided that this should be inspected first. Accordingly the line was shut off and dewatered. A manhole cover was removed and an access plate taken off so that it was possible to enter the main and inspect it. It was found that the line was in remarkably good condition considering its length of service. Very little tuberculation and no incrustation were present. The original coating had been an excellent job, but in numerous places it was completely gone and the bare steel was exposed. At the points where the steel was exposed, evidences of deterioration could be seen. After inspection the access plate was bolted up and the line restored to service.

Since the 36-in. ascending main had no access openings, inspection would have been extremely expensive. Therefore, tests were made on Aug. 29, 1940, to determine the coefficient of each line. The 48-in. lock-bar was found to have a coefficient of 108. The 36-in. cast-iron line was found to have a coefficient of 66. During the fall of 1940, plans were made for the rehabilitation of these two lines and in the spring of 1941 work was started which would eventually result in cement lining in both these lines *in situ* by a centrifugal process. It was decided to clean and cement-line the 48-in. line first and, after this was back in service, to clean and cement-line the 36-in. line.

Cleaning and Lining a 48-in. Line

In cleaning a steel line of this size there are a number of factors which must be considered, and planning and scheduling must anticipate these problems.

Because of surges which may occur during cleaning, with resulting negative pressures, it is imperative that air vents capable of handling large quantities of air be installed. These air vents, or vacuum breakers, preclude the possibility of collapsing the pipe when, for any reason, a vacuum occurs in the line. Figure 4 shows the air vents which were designed and installed for this purpose.

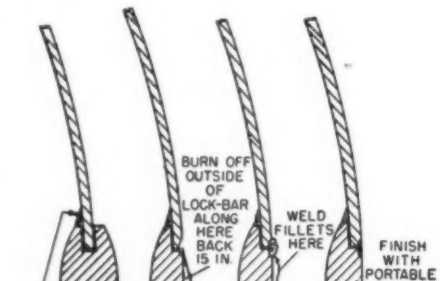


Fig. 5—Steps in the Preparation of Lock-Bar Pipe for Dresser Couplings.

As can be seen in the figure, the installation of such an air vent is rather simple. Using the plate of the air vent as a template, the welder cuts around all four sides of the plate after having set the plate so that its center line is on the vertical axis at the top of the pipe. The plate cut out is then removed and the hole in the pipe trimmed up. Then the frame for the vent is centered up over this hole and a heavy bead placed all around the frame on the outside. The gasket is then installed, the plate part of the vent lowered into the pipe and wedged up until ready for use.

The cleaning of the 48-in. lock-bar entailed the installation of two such vents; one in the nipple where the machine was introduced and the other at a point where access was had to determine whether or not there were stays in the line.

The vents gave two orifices at high points in the line, rectangular in cross-sections, 18x24 in., through which air could enter the line, and obviated all danger of collapsing the pipe.

Another danger in cleaning a line of this size is in allowing the machine to come out of the pipe, particularly on a down-hill shot. This danger obtains because of the piston effect of the machine. Should it be allowed to emerge completely, the sudden drop in water pressure in the line could conceivably cause the pipe to collapse. There is also the danger of spilling the tremendous quantities of water through the unobstructed pipe. To prevent this, it was necessary to build a very strong bulkhead in the hole where the machine was to make its exit, so that only part of the machine should leave the pipe and the piston-like skirt remain in the main, thereby causing the water to drain out of the line comparatively slowly. Plans for these bulkheads were made before the work started.

One of the problems to be considered in this job was the coupling up of lock-bar pipe. It was decided to use Dresser couplings for coupling up the nipples cut out for the entrance and exit of the cleaning and lining machines. Figure 5 shows the steps in the preparation of the pipe.

To prepare the pipe for the use of Dresser couplings it was necessary to cut off the outside of the lock-bar. The method used was to run two electric arc fillets along the inside joint of the lock-bars, both top and bottom, for a distance of 20 in. at both ends of the nipple. The lock bar was then undercut on the outside as shown in Fig. 5, and a fillet thrown on the outside which was finished off with a portable grinder, thus presenting a smooth surface on which the gaskets of the Dresser couplings could make a good seal. As can be seen from Fig. 5, the electric arc weld on the inside runs back for 20 in. and the cut of the lock-bar on the outside extends only 15 in. This overlap obviated any danger of a leak at this point. The lock-bars on the pipe projecting into the hole in the ground were treated in the same way except that the fillet on the inside was extended back only 12 in. and the cut on the outside 8 in. The Dresser couplings used had a width of 15 in. so that by placing the couplings on the nipple and dropping the nipple into place, then sliding the couplings over the pipe projecting into the hole, it was possible to center the Dresser sleeves over the cuts in the pipe.

An important step in planning such work is the selection of entrance and exit points for the cleaning machine. The exit point is particularly important because here it will be necessary to dispose of large quan-

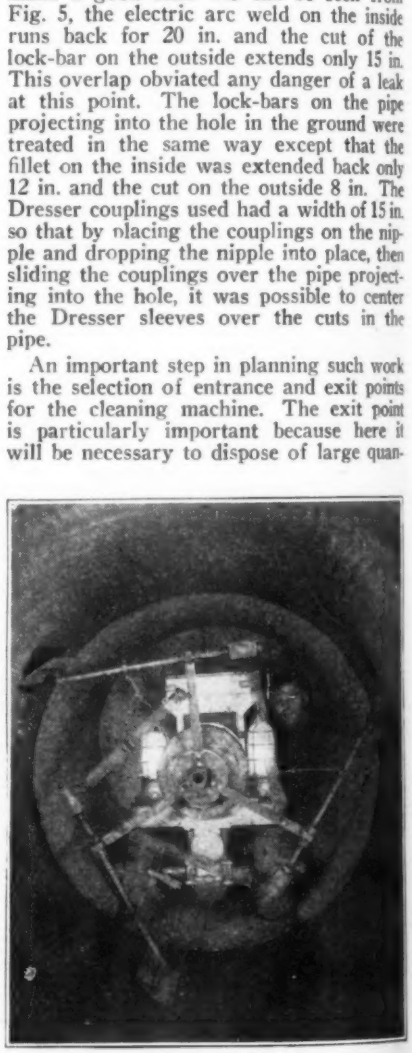


Fig. 6—Centriline Pipe Lining Machine in 36-in. Main.

Fig. 7—36-in. Line of Trenton Before Cleaning.

tities of water. After a careful study the points were selected and the planning phase of the job was completed.

Work was started on June 2, 1941. Three excavations were made for the cleaning, which involved shooting a cleaning tool by water pressure from the reservoir back to the pump station. An excavation, as close to the reservoir as possible without undue interference with the fittings, valves, etc., was made on the 48-in. line. This excavation was 12 ft. long, 8 ft. wide and 10 ft. deep, which left 2 ft. of working room all around and under the pipe. In Fig. 3 this excavation is shown at (A) on the plan. So that the large quantity of water discharged during cleaning could best be handled and emptied into the Delaware River, the exit excavation was made 100 ft. back from the gate at the pump house. This excavation was made at (B) on the plan. It was 12 ft. long, 8 ft. wide and approximately 10 ft. deep. The 2 ft. of working room around the pipe, which had been the objective, was interfered with in two places. At one point an 8-in. service main running from the pump house to the filter plant projected into the hole; on the other side a 60-in. concrete sewer cut down on the working room. This hole was "tight-sheeted," using 3x10 tongue and groove sheeting. On the side of the excavation nearest the river the sheeting was cut low and a flume fitted into the notch thus made. A flume 50 in. wide, 25 in. high and approximately 250 ft. long was constructed to convey the water overflowing through the notch in the sheeting into the Delaware River. Every effort was made to see that all preliminary work was completed before taking the line out of service so that the length of time the water was pumped through a single line—and the consequent higher pumping costs—would be held to a minimum.

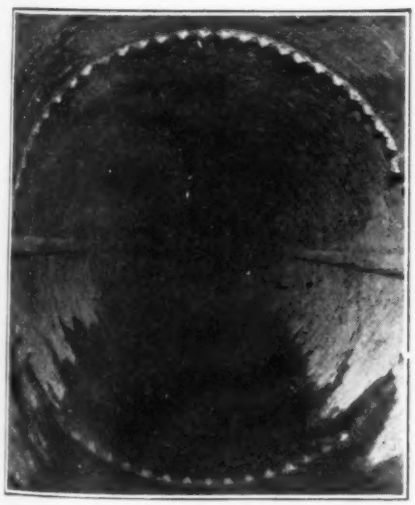


Fig. 9—Barrel of 48-in. Lock-Bar Main After Cleaning.

After all preparations had been made, the 48-in. lock-bar main was taken out of service on June 11. The line was shut off and the air valves checked to make sure they were in working order. A blowoff at a low point was opened and the line dewatered slowly to avoid the danger of pulling a vacuum and collapsing this steep pipe. The dewatering process took from noon on June 11 until 8 a.m. on June 12.

Using the oxyacetylene torch, a nipple 6 ft. 6 in. long was cut out of the 48-in. pipe at (A). Actually three cuts were made as 1 in. was cut off the nipple so that it could be easily put back into the main by using Dresser couplings. The nipple was lifted out of the ditch so that one of the automatic air vents (Fig. 4) could be installed; the cleaning tool was then jacked into the nipple and the lock-bar prepared for Dresser couplings, as illustrated in Fig. 5. The nipple, with the machine in it, was dropped into place in the line and coupled up with Dresser couplings.

A nipple was cut out at the exit hole and a bulkhead built to prevent the complete emergence of the cleaning machine and all was ready.

Through the co-operation of the Trenton police it was possible to secure the services of two two-way radio cars to facilitate the control operations. This was accomplished by leaving one radio car at the control valve so that the operator could immediately relay any instructions to the valve crew. The other radio car was used in following the machine so that it was possible at all times to increase or decrease the flow behind the machine.

Machine Speed Control Important

When all was in readiness, the valve was slowly opened behind the machine until the pressure reached approximately 8 lb. The machine started off and proceeded at a slow rate through the pipe. The last 2,000 ft. of this line have a very sharp down-grade. As soon as the top of the grade was reached, the large quantity of water contained in the 5,000 ft. of pipe behind the machine was converted into head and, as the pressure increased, the speed of the machine increased so that its travel through the last 1,500 ft. was very rapid. During the shot it was found that with a pressure of approximately 8 lb. behind the machine, water at a 22-mgd. rate was consumed.

An inspection of the pipeline after this shot showed that, at the beginning of the line where the progress of the machine had been slow, the cleaning was a thorough job, but that the last 1,500 ft. of the shot had not given a very good cleaning job due to the rapidity with which the machine had traveled through this section of pipe. It was decided to shoot the machine again to see if it would be possible, by shutting off the water before the down-grade was reached, to control the speed of the machine so that a more thorough job of cleaning could be accomplished. This was attempted on June 20, 1941, but it was impossible to hold down the speed of the machine to a desirable point.

Two-Way Cleaning Proves Meritorious

It was then decided to shoot the machine uphill, that is, from hole (B) (in Fig. 3) toward hole (A), using the pumps at the pump station as a source of pressure. This necessitated the "tight-sheeting" of the hole at (A) and the building of a rugged bulkhead at this point so that the machine would not come all the way out of the pipe with a resulting surge of water.

Fig. 8—A Section from the 36-in. Steel Main Reveals the Urgent Need for Some Form of Rehabilitation.

The fact that the point where the wash water was to be disposed of was in a rather heavily populated district presented another problem in shooting uphill. It was necessary, therefore, to make a survey of the sewer system in the area to determine how to dispose of the large quantity of water which would be discharged during the shot. The problem was solved by sandbagging along the curbs of the streets and distributing the load over a number of large storm sewers. When all of the preparatory work was completed the machine was shot uphill and, in this process, it was possible to control its speed very accurately, using the radio cars as a means of communication with the pump house.

After this uphill shot the line was found to be properly cleaned and was ready for the cement lining.

Lining Operations

The 48-in. cement-lining machine is powered by an electric motor and travels through the pipe, applying the mortar centrifugally as it travels. It is followed by adjustable rotary trowels. Current for the motor is supplied through a cable which is run inside the pipe back to a mobile alternator. As the lining machine travels back through the pipe, the cable is pulled toward the alternator and wound up on a reel.

The cement mortar is mixed in a mobile

Fig. 10—The Completed Job on the 48-in. Main—and Good Now for at Least 50 Years More, with Sustained Delivery Capacity.

wet batching machine. The mortar is dropped through the chute at the hopper and into rubber-tired buggies placed below it inside the pipe. The buggy, full of mortar, is pushed to the lining-machine, the mortar transferred to the hopper of the lining-machine and the buggy returned for another load of mortar.

Figure 3 shows how the lining machine was inserted in the pipe at the hole near the filter plant and run back toward the pump station. The batching machine and the alternator were located at this hole and the pipe was lined from the gate at the pump house back to the hole. The batcher and the alternator were moved to the first access hole, the nipple dropped into place, coupled up and the machine placed the lining right through the nipple.

Because of the mortar transportation problem it was necessary to have small holes about every 1,000 ft. so that the wet-mix concrete could be dumped through a chute into buggies on the inside of the main at these points, and transported for shorter distance to the lining-machine itself. It will be seen on the plan that there were a number of small excavations where this was done. After the lining was completed, the manholes were bolted back and the lining was made one continuous cylinder right past these access manholes.

When the exit hole at the far end was reached, the machine was turned around and sent up into the pipe at the far end. The pipe was lined back to the hole, the lining machine lifted out of the hole, the nipple lined up on the ground, lowered into place and coupled up. Thus a continuous lining was provided from one end of the line to the other.

The line was sterilized and put back in service on July 31. The sterilization was accomplished by feeding water containing chlorine to the extent of 60 ppm. and running it right through into the reservoir. Although this water as it entered the reservoir had a very high residual, there never was detected any increase in residual in the distribution system.

With the 48-in. line back in service—it had been out of service only 38 working days—it was now possible to go ahead with the cleaning and cement-lining of the 36-in. line.

Cleaning and Lining a 36-in. Line

The 36-in. line was laid in 1870 and there was no record of some of the older connections to it. This line was shut off on Aug. 1, 1941, and with the 36-in. line off, a test was run on the 48-in. line for leakage. We were unable to measure any leakage in this line after cleaning and cement lining, although the test was run over a 24-hour period.

On Aug. 2 the 36-in. line was de-watered by running the water out through a 16-in. side connection. An attempt was made to cut the cast-iron pipe by means of the electric arc at the point (E) which was to be the entrance hole for the cleaning machine. The attempt was not successful because it was impossible to obtain an electric arc welder having a capacity larger than 200 amp. and, for the successful cutting of this thickness of cast-iron, a machine of at least 600-amp. capacity is required. This nipple was finally cut out using an oxy-acetylene cutting torch of special design and the results obtained with this method of cutting were very good, as were the results of the cutting at the exit hole (F).

The 36-in. cleaning machine was placed in the nipple which had been cut at (E) in Fig. 3 and, on the night of Aug. 5, when everything was in readiness, the shot was made.

In the course of this shot the machine negotiated two short-radius 90-deg. bends. Examination of the pipe showed that a very good job of cleaning had been done but that an additional shot would be necessary to attain the smooth condition needed for a good cement lining job.

A second shot was made during the night of Aug. 6 and examination of the pipe after this shot showed that an excellent job of cleaning had been done and that the pipe was ready for cement lining.

Fig. 6 shows the 36-in. lining machine operating within the main.

Access for cement lining was had at a number of points indicated on the plan (Fig. 3), and manholes were fabricated by drilling a series of holes making a circular piece which could be broken out of the top of the pipe. A saddle was then fastened to the pipe and a cast-iron plate fastened in this saddle. No particular difficulties were experienced during the lining of the 36-in. pipe and the work was completed on Aug. 21, 1941. The line was sterilized, using the same quantities of chlorine and procedure employed on the 48-in. line.

Results

A test for capacity and coefficient was made on these two lines more than two years later. The 48-in. line was found to have a coefficient of 144 and the 36-in. line a value of 135, as compared with 108 and 66, respectively, before rehabilitation. These coefficients are corrected for the reduction in area due to the thickness of the cement lining.

The reduced friction loss results in considerable power saving, amounting to from 15 to 17 per cent.

Fig. 7 shows the 36-in. line before cleaning. Note the flow-impeding tuberculation.

Fig. 8 shows the condition of a portion of the steel main discovered during the lining process. It can readily be seen that the corroded and pitted condition was serious and would soon have led to trouble.

Fig. 9 shows a section of the 48-in. main after two-way cleaning and ready for cement lining.

Fig. 10 is a view of the same line after lining. The lining is extremely smooth. The illusion of rings or large circumferential corrugations is a light reflection phenomena.

Another result of the cement lining is that the old lines have been made bottle-tight. In the five-year period preceding the cement lining of these two mains, leakages bad enough to need repair were found on the average of eight times per year. Since the completion of this work in 1941 not one leak has been discovered on the 48-in. line. In addition, a test run on the 48-in. and 36-in. lines together showed a leakage so small that it is practically impossible to measure it.

The job has been of great benefit since costly repairs, which would have been necessary, have been obviated. The two lines are bottle-tight and the friction loss has been reduced so that pumping costs are held to the value for new pipe.

Another advantage, which is difficult to evaluate, is that the life of the failing lock-bar line has been increased at least 50 years. This, in itself, is worth many times the cost of the cleaning and cement lining.

Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters ÷ 2.54 = inches.
Meters × 39.37 = inches (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers × 3280.8693 = feet.
Square Millimeters × .00155 = sq. inches.
Square Millimeters ÷ 645.1 = sq. inches.
Square Centimeters × .155 = sq. inches.
Square Centimeters ÷ 6.451 = sq. inches.
Square Meters × 10.764 = sq. feet.
Square Kilometers × 247.1 = acres.
Hectare × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.
Cubic Centimeters ÷ 3.69 = fl. drams (U. S. P.).
Cubic Centimeters ÷ 29.57 = fluid ounces (U.S.P.).
Cubic Meters × 35.315 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons (231. cubic inches).
Liters × 61.022 = cu. in. (Act of Congress).
Liters × 33.84 = fluid ounces (U. S. P.)
Liters × .2642 = gallons (231. cu. in.).
Liters ÷ 3.78 = gallons (231. cu. in.).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cu. in.).
Hectoliters × .131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231. cu. in.).
Grams × 15.432 = grains (Act of Congress).
Grams ÷ 981. = dynes.
Grams (water) ÷ 29.57 = fluid ounces.
Grams ÷ 28.35 = ounces avoirdupois.
Grams per Cu. Cent. ÷ 27.7 = lbs. per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = oz. avoirdupois.
Kilograms ÷ 907.2 = tons (2,000 lbs.)
Kilograms per Sq. Cent. × 14.223 = lbs. per sq. in.
Kilogram-meters × 7.233 = foot lbs.
Kilograms per Meter × .672 = lbs. per foot.
Kilograms per Cu. Meter × .062 = lbs. per cubic foot.
Tonneau × 1.1023 = tons (2,000 lbs.).
Kilowatts × 1.34 = Horse Power.
Watts ÷ 746. = Horse Power.
Watts × .7373 = foot pounds per second.
Calorie × 3.968 = B.t.u.
Cheval vapeur ÷ .9863 = Horse Power.
(Centigrade × 1.8) + 32 = degrees Fahr.
Gravity Paris = 980.94 centimeters per sec.

COMPRESSED AIR FLUSHING OF SMALL MAINS

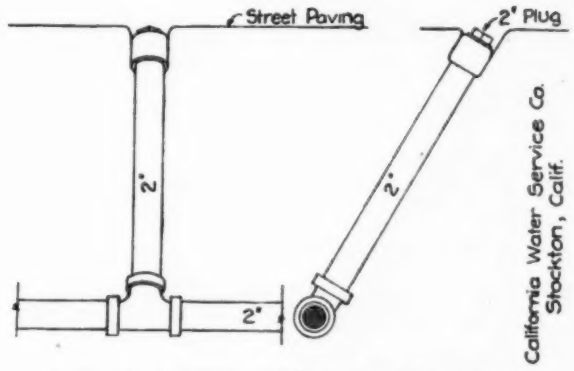
By R. F. BROWN

Plant Manager, California Water Service Co., Stockton, California

MANY water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

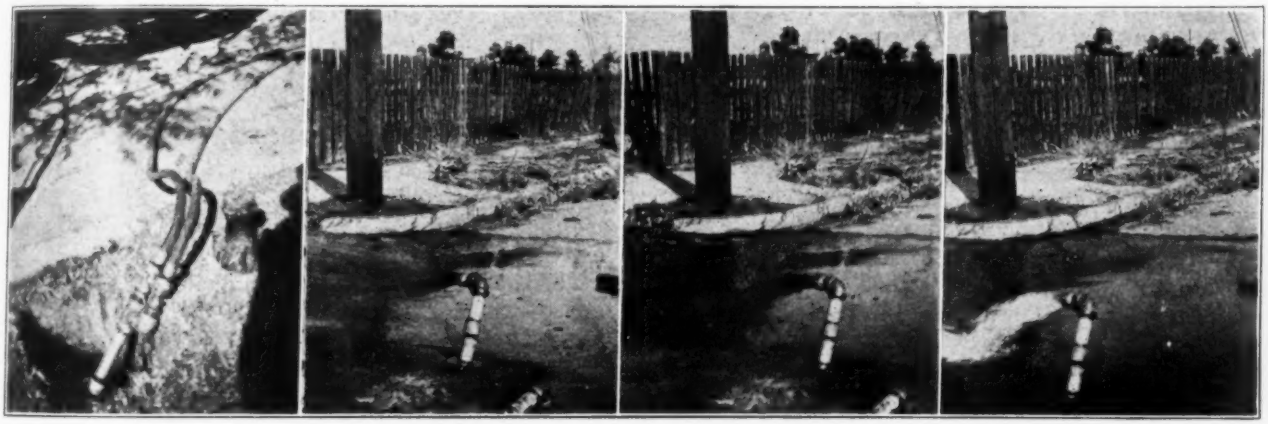
pose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

This system is apparently successful in accomplishing our pur-

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus,
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Recent developments in water works practice show that bacteria practically cease to exist where Free Residual Chlorination, as accomplished by the Break-Point Process, is employed. Such chlorination assures the production of free available chlorine residuals which have a high killing potential. In many plants bacterial control by the Break-Point Process has been augmented with additional benefits such as improved coagulation, increased color removal, elimination of algal conditions, reduced chemical costs and increased length of filter runs with a resultant saving in wash water.

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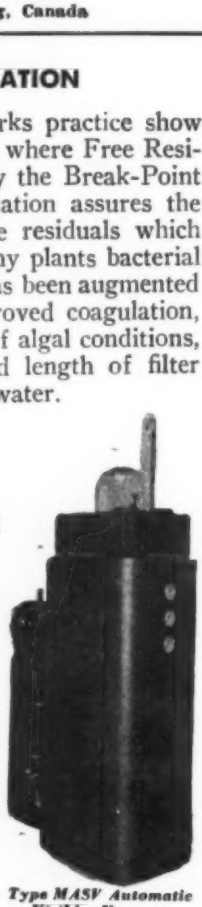
Where unusual or extreme fluctuations in water or sewage flow are encountered, the Type MASV meets the chlorination requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator — rugged construction, simplicity of operation and low maintenance costs.



Type MASV Automatic Visible Vacuum Chlorinator

THE W&T HYPOCHLORINATOR

W&T Hypochlorinator

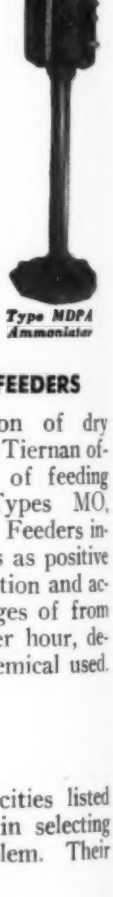
Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochloride in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

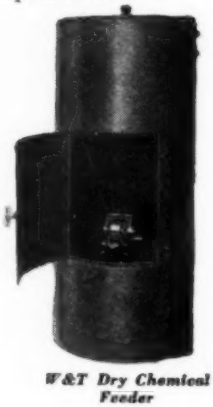
The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

TYPE MDPA DIRECT FEED AMMONIATOR

A self-contained unit specially adapted to handling ammonia gas, embodying the same sound principles of design and construction exemplified in W&T Chlorinators. Rugged, accurate and dependable.



Type MDPA Ammoniator



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W&T is represented in each of the 36 cities listed above by chlorination specialists to assist in selecting proper equipment for any chlorination problem. Their recommendations involve no obligation.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

CHECKING TUBERCULATION BY CHLORAMINE TREATMENT

By J. WALTER ACKERMAN*

Water Production Div., War Production Board, Washington, D. C.

The results from the ammonia-chlorine treatment in suppressing tuberculation of the 12-mile cast-iron supply main at Utica, N. Y., constitute a new chapter in corrosion control and depreciating capacity values of water mains.

When Mr. Ackerman first reported his observations informally before the American Water Works Association in 1934, he considered the findings both interesting and indicative, rather than conclusive. Amongst his audience were many skeptics. A year later sufficient supporting data had been accumulated by him to warrant a further informal report before the same association. Now, still a year later, the results are more than ever convincing. It was with thtis in mind that WATER WORKS AND SEWERAGE *asked Mr. Ackerman to present to its readers his data-graphs and the accompanying report of the continuing effectiveness of the treatment which maintains sterile conditions throughout the 12-mile main.—Editor.*

The Consolidated Water Co. of Utica, N. Y., constructed in 1906 a single 24-inch cast iron water main for transmission purposes to bring water from the West Canada Creek at Hinckley, N. Y., to Marcy Summit, a distance of 12.1 miles, for the purpose of supplying the city of Utica with water from this source in addition to that already supplied from the southern group of reservoirs. This supplied sufficient water for use in the city until 1922, when the use had increased and delivery of this line had diminished to a point where it was only delivering about 8.5 M.G.D.

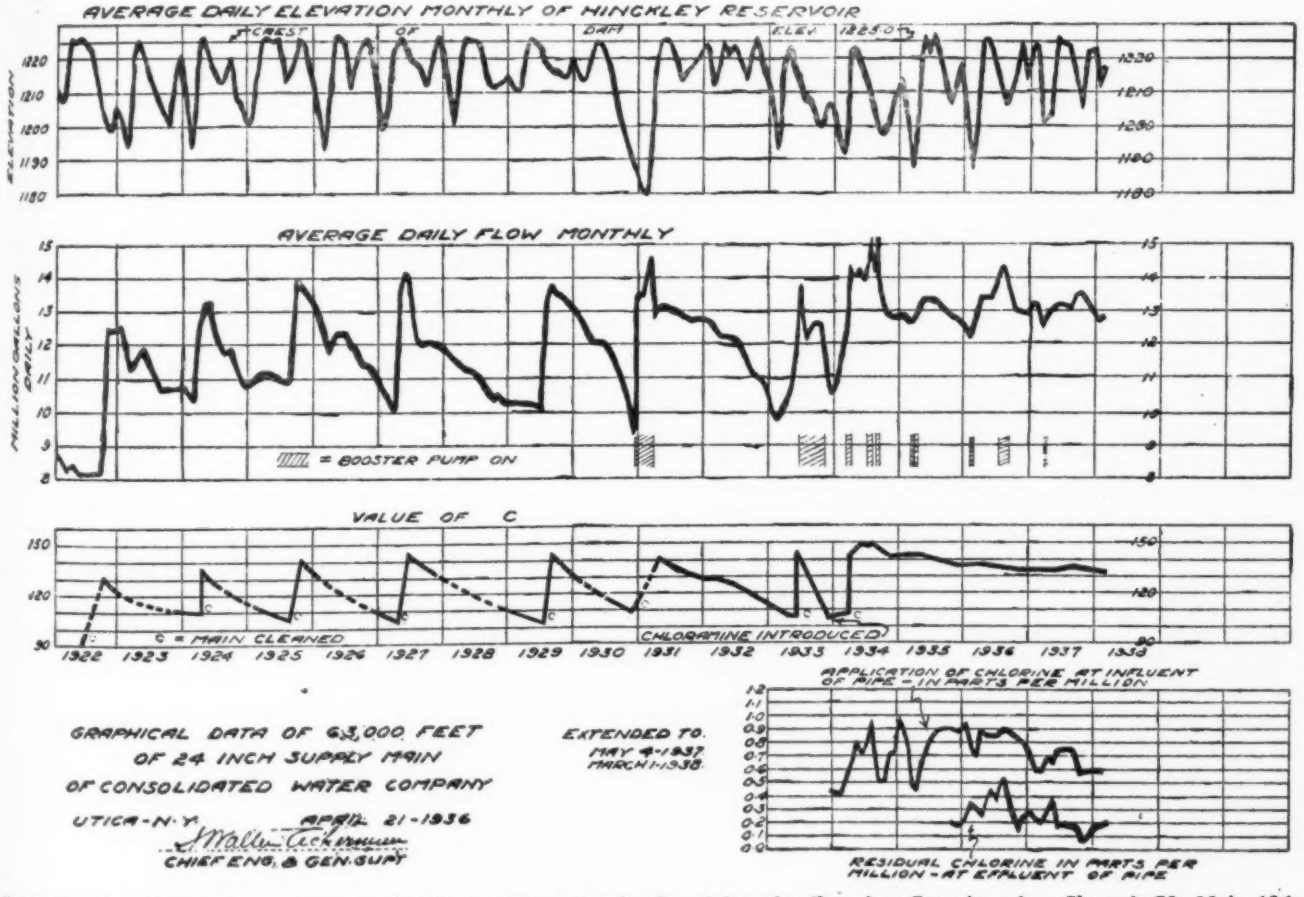
**General Superintendent, Consolidated Water Co., Utica, N. Y., when this article was written.*

Records in the office indicate that in 1917 this line was examined by Metcalf & Eddy, Engineers, and the value of "C" in the Hazen-Williams formula was found to be 109. On July 5, 1921, "C" had dropped to 95, and in November of the same year it had dropped further to 93.5. It later became necessary to clean this line and the National Water Main Cleaning Company was engaged for this purpose and cleaned it on October 5, 1922.

Table A shows the number of times the main has been cleaned since that date and the various "C" values before and after cleaning.

TABLE A

Date Cleaned	Months Since Previous Cleaning	Reservoir Elevation	—Delivery— Before	After	—"C"— Before	After
		1199.9	Oct. '22	Oct. '22	June '22	Oct. 8, '22
Oct. 5, 1922		1199.9	8.5	12.3	90	131
		1192.3	Mar. '24	May '22		
Apr. 1, 1924	18	1226.1	10.3	13.2	109	136
		1211.8	Aug. '25	Oct. '25		
Aug. 27, 1925	17	1220.4	10.5	13 9	106	142
		1222.7	Apr. '27	June '27		
May 4, 1927	20	1223.1	10.1	14.2	103	144
		1223.7	July '29	Sept. '29		
Aug. 6, 1929	27	1215.6	10.0	13.8	102	142
		1193.3	Nov. '30	Mar. '31	Nov. '30	Sept. '31
Jan. 3, 1931	17	1249.7	10.2	14.6	109	133
		1223.6	May '33	July '33	Apr. '33	July '33
June 16, 1933	29	1273.8	10.3	14.0	106	136
		1276.4	Apr.2,'34	Apr.12,'34		
Apr. 8, 1934	10	1226.1	11.9	13.7	111	144


AVERAGE DAILY ELEVATION MONTHLY OF HINCKLEY RESERVOIR
CREST OF DAM ELEV 1225.0
ELEVATION
AVERAGE DAILY FLOW MONTHLY
MILLION GALLONS DAILY
= BOOSTER PUMP ON
VALUE OF C
C = MAIN CLEANED
CHLORAMINE INTRODUCED
1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938
APPLICATION OF CHLORINE AT INFLUENT OF PIPE - IN PARTS PER MILLION
RESIDUAL CHLORINE IN PARTS PER MILLION - AT EFFLUENT OF PIPE
GRAPHICAL DATA OF 63,000 FEET OF 24 INCH SUPPLY MAIN OF CONSOLIDATED WATER COMPANY
UTICA - N.Y. APRIL 21 - 1936
CHIEF ENG. & GEN. SUPT.
EXTENDED TO MAY 4-1937 MARCH 1-1938

Graph Showing Effectiveness of Ammonia-Chlorine Treatment in Sustaining the Carrying Capacity of a Cleaned CI. Main 12.1 Miles in Length. Compare the Friction Coefficient Curve for 1930 and 1934 with that for 1934-1938

Until December, 1933, this 24-inch line had carried nothing but untreated water, chlorination being carried out at the local distributing reservoirs. In December, 1933, chlorine-ammonia treatment of the water was started at Hinckley, and the "C" value at the time the treatment began was 105. In April, 1934, just prior to the last cleaning, a measurement of "C" showed a value of 111, an apparent improvement of about 6 p.c. in carrying capacity after the four months of treatment by chloramines, without cleaning.

The last cleaning of this line was done as noted on April 8, 1934, and the "C" value was raised from 111 to 144. No mechanical cleaning has been done since that date, but the line has been continuously treated with chloramines to the present time.

The graph accompanying this article shows the variations in the level of the water in the Hinckley Reservoir, which varies the head on this pipe line and consequently varies the flow due to this change in head. It shows the monthly average flow in each month from 1922 to date, also the chlorine application and the resultant "C" value before and since the application of the ammonia-chlorine treatment. The results seemingly speak for themselves.

Method of Checking "C" Value

Just a word as to the method of checking this "C" value. Careful and rechecked determinations of reference level points at each end of the 12.1 miles of pipe have been made. Consequently, physical observations of the water level in the standpipe at one end of the line and the water level at Hinckley Dam at the other end give the actual slope. The amount of flow is determined by a venturi meter, but at no time has the value of the amount of flow been accepted except after being checked by manometer or pitot tube, and, in fact, a number of these determinations are made either by the manometer on the venturi tube or the pitot tube near this same place. Therefore there are some slight variations in the determining of the "C" value of the period from April, 1934, to the present time. While there appears to be somewhat of a downward trend, it is so small as to be almost negligible, as, of course, the different methods of computing the flow vary about 2 to 3 per cent, according to the method used for this determination, which is as close as can be expected for equipment of this nature.

The Marcy standpipe, which is at the lower end of the 12.1 miles of 24-inch pipe in question, is 2.3 miles from Marcy Reservoir, where the actual chlorine residual is taken, as the Marcy standpipe is in a more or less inaccessible location a part of the year. The residual obtained and shown on the chart is less, therefore, than the actual residual at the end of the 12.1 miles of 24-inch pipe, as the chlorine demand in the 2.3 miles to Marcy Reservoir is considerable in this uncleaned and badly tuberculated section of pipe, which we believe is gradually being cleaned by the action of the chloramines.

Addenda—1937-1938

The above article was prepared in April, 1936. From Mr. Ackerman comes the following advice and a new graph, which carries forward the flow and friction data into 1938, although the graph carries the original date—April 21, 1936. The author explains that the data are checked by frequent readings taken from a checking manometer on the venturi tube, and the use of a Cole rod and Lanham rod. These check readings have shown a difference of but 1 to 3 points in obtaining "C" values of 134 to 142 in the Utica situation.

Mr. Ackerman states: "It will be noted that there seems to be a slight diminution of the "C" value during the past year, but hardly enough to make very much difference in our flow. As a matter of fact we are actually getting more water down now than heretofore, which, I think, is due to the fact that all of these figures constitute the result between the Hinckley Dam and our Marcy standpipe only."

"Below the Marcy standpipe to our reservoirs are two lines of pipe, one 24-inch and one a 16-inch. We know that the 16-inch is very badly tuberculated. About three years ago a test was made on it and the "C" value was down to about 60. But, since we had at least a theoretical capacity greater than the line above, we did not clean these two lines. We do find now that the water does not stand as high in our standpipe with the same dam elevation at Hinckley as heretofore, which rather indicates that the chloramines have been gradually cleaning the 16 and 24-inch lines below the Marcy standpipe."

"These are just some added points to give you a better understanding of the problem."

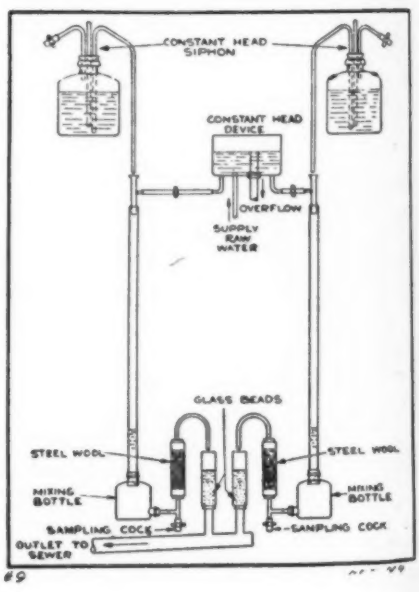
CORROSIVITY INDICATOR

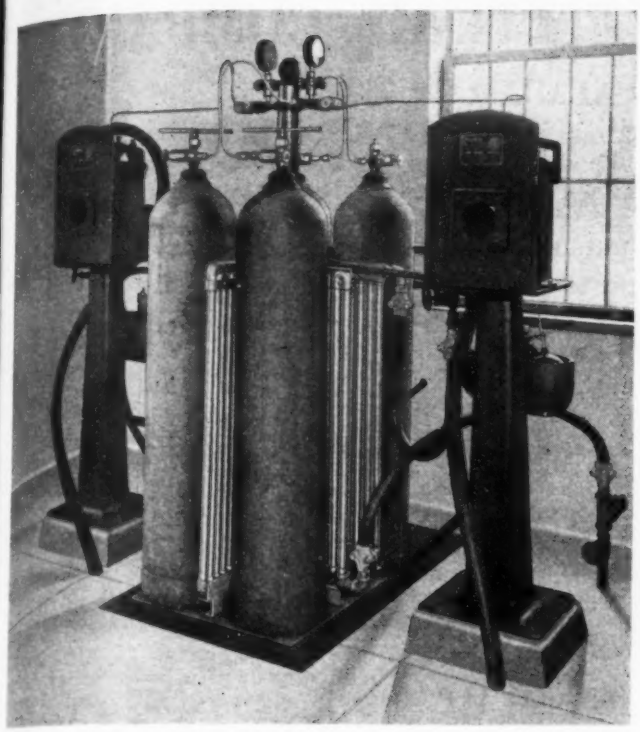
THE accompanying sketch pictures a very effective piece of equipment devised and employed by Hall Laboratores, Inc., to study and demonstrate the efficacy of various treatments applied to waters for corrosion or scaling control.

The scheme involves passage of the water under treatment, for comparison, upwards through clean, bright steel-wool. The effluents leaving the wool contact chamber drip through clean glass beads.

The rapidity and relative intensity with which the steel rusts and the beads become iron-stained constitute a convincing semi-quantitative index of corrosivity. For greater exactness in comparison samples of effluent from the steel corrosive chamber are analyzed for iron, oxygen, etc.

It is evident that this apparatus can be employed with lead wool, copper-sponge, etc., to study action on these and other materials. A battery of as many units as required may be set up. The device has considerable resemblance to the Enslow Continuous Stability Indicator.





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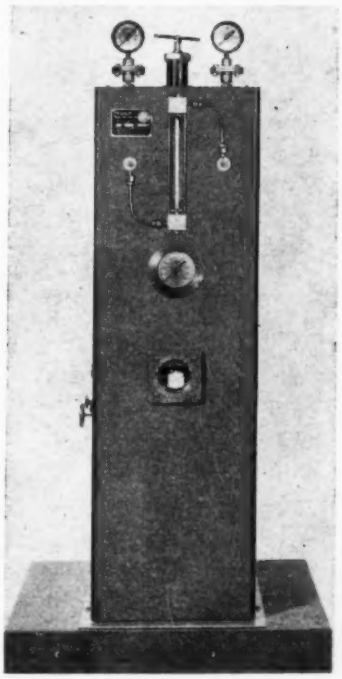
Left—High Capacity CHEMCO CHLORINATOR installation for State of New York sewage plant.



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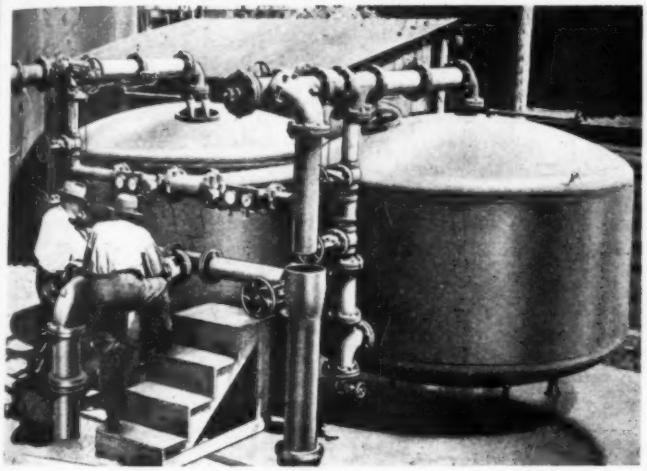

CHEMCO Pressure Filter installations provide many simplications over conventional type of commercial installation and are designed, fabricated and installed for each individual requirement. Engineered for long, low cost service. Also available as wood tanks, pressure or gravity filters. Illustration at left shows large CHEMCO FILTER installation for Santa Fe Railroad.

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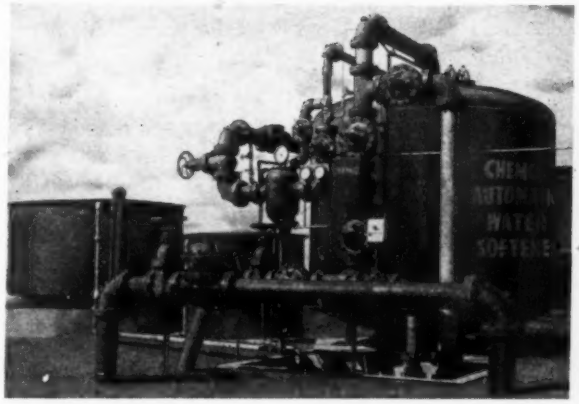

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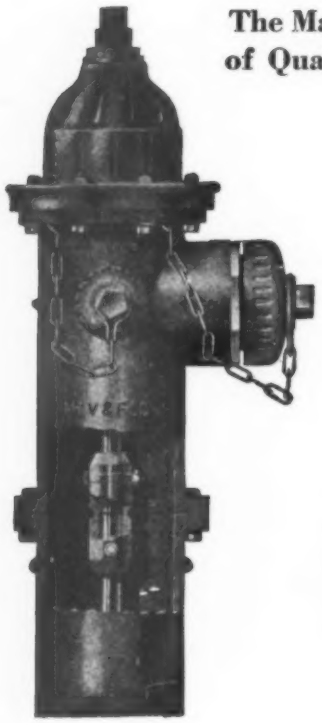

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5. **Lengthening of Hydrant without digging up or requiring complete new barrel.**
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A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

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HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON
Water Works Consultant, Glen Ridge, N. J

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can debate for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings) Hydrant Pitot Tube with Gage at Right

Methods of Measuring Hydrant Discharge

Measurement of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center of the stream will approximate the average pressure. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained a diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

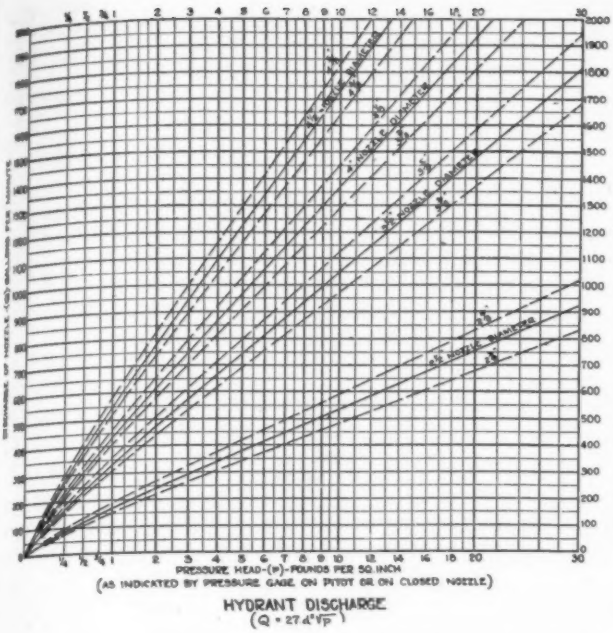
TABLE 1—HYDRANT DISCHARGE*

Gallons per minute = $27\ d^2\ \sqrt{p}$

Gage Reading—Hydrant nozzle diameter in inches [d]

p	2⅛	2¼	2⅜	2½	2⅝	2¾
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	450
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	990
30	790	830	880	920	970	1030

*Discharges shown to nearest 10 gals. per min.



Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary.

Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280$$ gal. per min. which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1 is the measured discharge with a drop in pressure of D_1; and Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/4-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 1/4-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

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Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

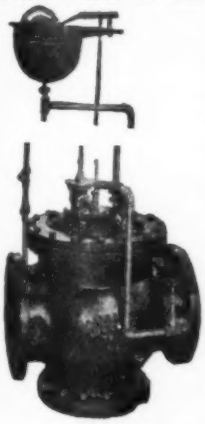
Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Intaliled in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller



Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

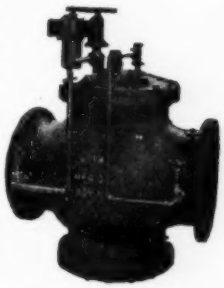
Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.



Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

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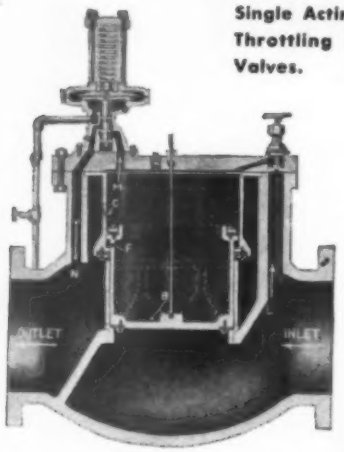

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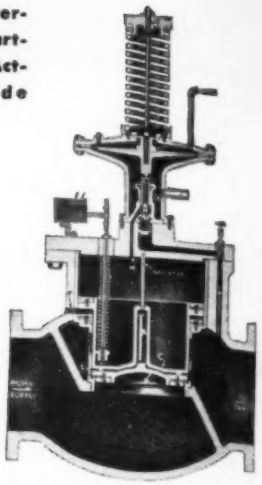
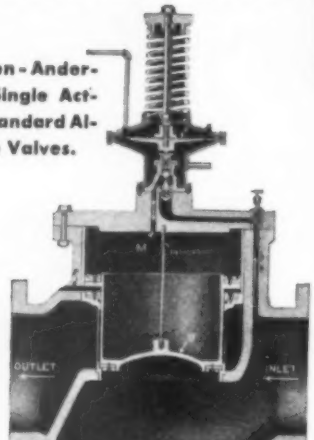


Golden-Anderson Single Acting Standard Altitude Valves.



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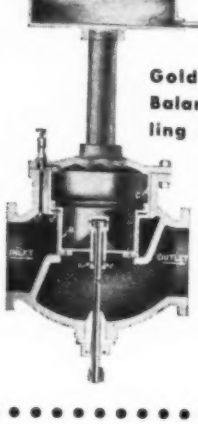

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ESTIMATING FLOWS FROM LOW PRESSURE FIRE HYDRANTS

A Method Also Applicable to Free-Falling Flow From Pipe Lines, Sewers, Etc.

By A. A. HIRSCH*
State Department of Education, Baton Rouge, La.

IN MEASURING flows from a fire hydrant, when the stream does not issue with jet force, or when the nozzle flows only partly full, a method based on measuring the trajectory or path of the stream is most convenient and best suited to the situation.

Small flows from fire hydrants are encountered when conducting fire flow tests in towns having deficient distribution systems. This is especially true on the outskirts where pressure may be entirely lost if more than a single fire hydrant is opened. Also the method is useful when adjusting the flow through new or repaired sections of pipe for continuous heavy chlorination. The method is likewise useful in estimating flows from pipes in general where a free fall of the stream from a smooth end section of pipe can be arranged. Although no great accuracy is claimed for the method it is sufficiently accurate for utilization under many conditions.

Description of Method

Known under various names as the X-Y method, the coordinate method, and the trajectory method, the procedure consists simply in measuring the distance that the stream has been projected after it has fallen some measured distance. Different modifications measure the deflection according to various detail, thus the reference point in the stream may be along its top, its estimated center, or the underside, whichever system seems best adapted to the purpose at hand. For use in connection with fire hydrant flow, measurement but to the underside of the stream seems desirable for simplicity and convenience.

As shown in Fig. 1, this deflection is for convenience measured at a level 1 foot below the invert of the nozzle. The tape or measuring rod is extended horizontally to a point where its tip just touches the main stream; no attention is paid to irregular side currents that might not be thrown out so far. Drops shorter than one foot result in smaller projections (shorter trajectory) which increase the error in measurement, while longer drops are not applicable for low setting hydrants.

The relation between the deflection and rate of flow is best established by direct calibration. A tank of known volume, say a cask or a milk can, is placed to catch the stream from a high setting hydrant and the time required for filling noted for various openings of the valve. The deflection is also measured several times for each valve setting and averaged. From these data a calibration curve such as Fig. 2, for a 2½-inch nozzle, may be plotted.

[If a special composite rule is used, as described later, this curve will vary slightly according to the manner in which the drop tape is assembled to the case of the horizontal rule.]

Calibration Curve

On logarithmic paper the calibration curve consists of two segments, the lower one corresponding to flow over a broad crested circular weir, and the upper one characteristic of forced flow through a tubular orifice; these cases refer to a partially full nozzle and a completely full nozzle respectively. So long as the nozzle is only partly full an increment in head and cross section of the stream is not accompanied by a proportional increment in projection, since the stream is not forcibly expelled under pressure. Hence for low flows the curve flattens as indicated. Within this region two types of flow can be recognized, namely, a relatively quiet spillover at very low discharge, and a twisting stream having elevated sides when flowing over half full.

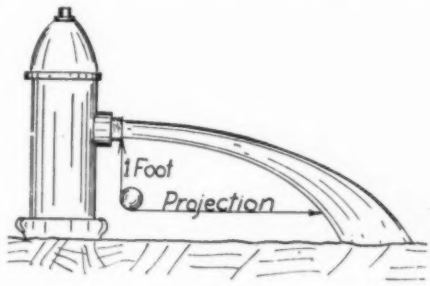


Fig. 1. Trajectory Method for Measuring Flow from a Fire Hydrant

At full discharge, starting near 65 gpm., the curve is a straight line having unit slope as expected from theory. When the flow exceeds 250 gpm. the water is blown out at a wide angle, causing deflections of the underside to actually decrease. Therefore, a practical upper limit for use of this method is set by divergence of the stream, although if no other method were available in the higher range, the bottom trajectory curve still might be extended somewhat beyond the recession point.

Theoretical Relations

The equation for that portion of the calibration curve representing the trajectory of a jet under pressure has been derived in textbooks simply by noting that the horizontal component of the velocity is given by the usual nozzle formula and the vertical component is governed by the law for speed of falling bodies. Thus there is always a fixed relation between the vertical drop, the projected travel horizontally, and the rate of flow. In applying this method the drop, for convenience, is set arbitrarily at one foot. The projected throw is measured and the rate of flow thereby established.

Let:

- x = horizontal travel of stream, ft.
- y = vertical drop of stream, ft.
- v = velocity of discharge from nozzle, ft./sec.
- g = acceleration due to gravity, ft./sec.^{2}
- t = time of flow, sec.
- h = head over nozzle, ft. water.
- A = cross-sectional area of nozzle, sq. ft.
- q = quantity, cu ft./sec.

The horizontal motion of the jet during time (t) is

$$x = vt \quad \text{.....Eq. (1)}$$

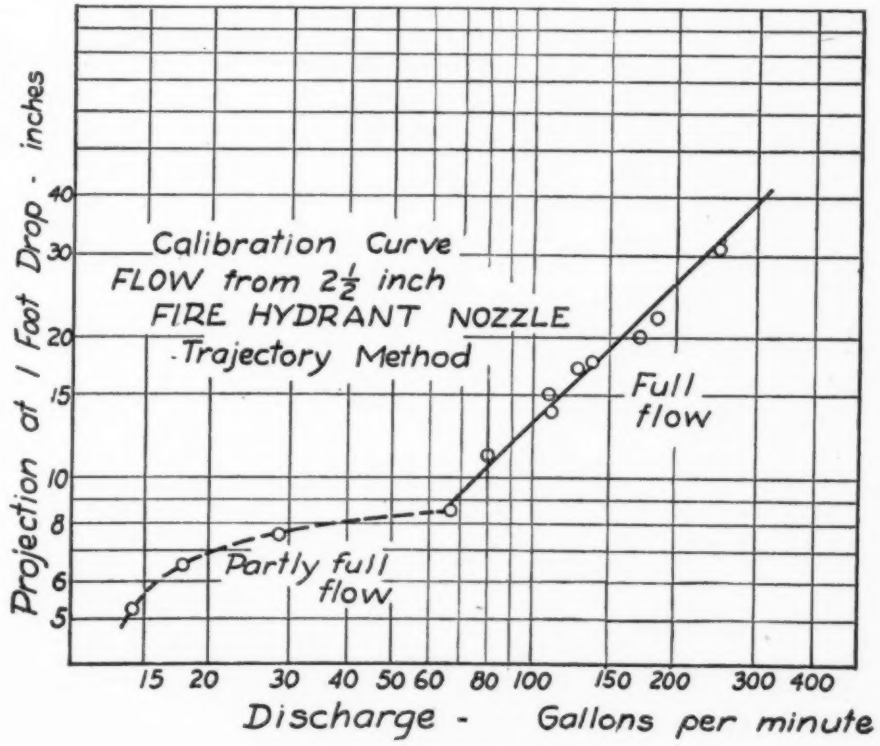


Fig. 2. Typical Calibration Curve

*Director, Sectional School on Water Supply and Sewerage.

while the vertical fall is

$$y = \tfrac{1}{2}gt^2 \quad \text{.....Eq. (2)}$$

eliminating the factor (t)

$$x = v\sqrt{\frac{2y}{g}} \quad \text{.....Eq. (3)}$$

since $q = Av$

Then,

$$x = \frac{q}{A}\sqrt{\frac{2y}{g}} \quad \text{.....Eq. (4)}$$

which shows that the horizontal projection, at any fixed level, varies directly with the rate of flow. Substituting numerical values in Eq. (4) and expressing flow in gallons per minute the flow in cu. ft./sec. (q) becomes gpm. divided by 7.48 (gal. in 1 cu. ft.) times 60—

And

$$x = \frac{\text{gpm.}}{\dfrac{7.48 \times 60}{.785 \times 2.5 \times 2.5}} \times \sqrt{\frac{2 \times 1}{32.16}}$$

$$= \frac{\text{gpm.}}{144}$$

$$= 0.01658 \times \text{gpm.}$$

If the projected distance is measured in inches

$$x_{\text{(inches)}} = 12 \times 0.01658 \text{ gpm.}$$

$$= 0.199 \times \text{gpm.}$$

or 100 gpm. causes a deflection of 19.9 inches.

This derivation is based on average displacement, as from the center of the nozzle tip to the center of the stream, and checks closely other data obtained under such conditions. When the distance to the underside of the jet is measured, however, it is found, as shown on the calibration curve, that 100 gpm. flows at a deflection of only 13.0 inches. This smaller projection is due to widening of the stream both hydraulically and geometrically as cut by a horizontal transept.

Special Rule

Rather than measure deflection of a stream and refer to the calibration chart, the rule (such as an encased steel tape) may be divided (by means of painted marks) as indicated in Fig. 3, to express flow directly. A completely self-contained device to set the level at one foot drop and to measure out to the stream, as in Fig. 1, may be made by attaching a short auxiliary steel tape to the case of the main rule in such a way that when applied to the hydrant the required level is established. This drop tape may be attached in a number of ways depending on the type of case. The simplest possibility is with cases having a hollow central rivet through which the drop tape may be bolted. The assembly can then be compactly wound and carried in a small pouch of soft leather or cloth.

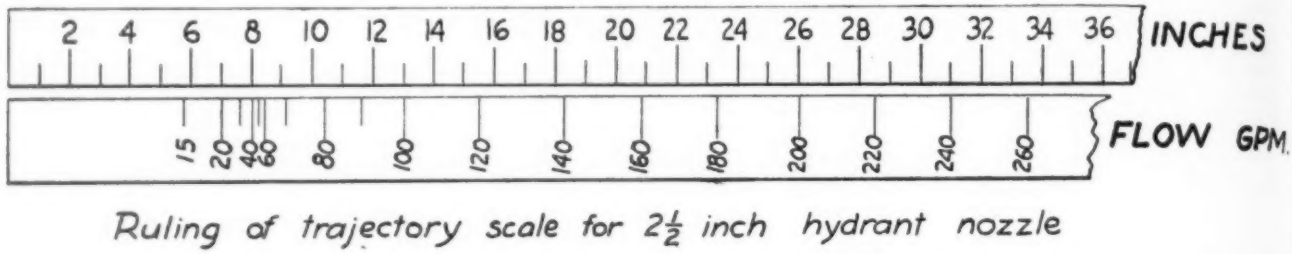


Fig. 3. Ruling of Trajectory Scale for 2½-In. Hydrant Nozzle

INCLINED DIAGONAL PIPE RUNS CALCULATING PIPE LENGTHS

By CHARLES FRICK

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (Θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\Theta) = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (Θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$

$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\Theta) = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$

$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (Θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (Θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\Theta) \qquad \text{Formula III}$$

$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\Theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (Θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$

$$= \sqrt{64 + 90.25} \times 1.4142$$

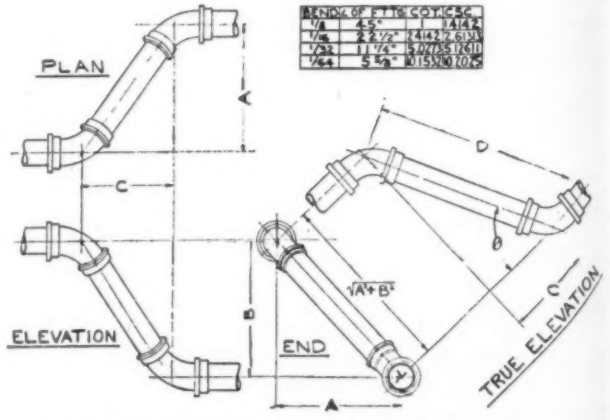
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$

$$= \sqrt{64 + 90.25} \times 1$$

$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

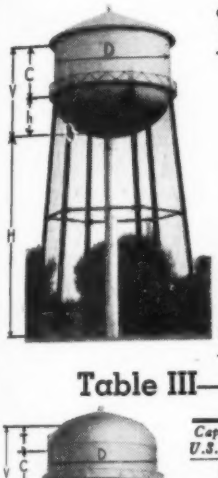
Sales Offices at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE STREET, DES MOINES, IOWA
ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL.
1223 PRAETORIAN BLDG., DALLAS, TEX. . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks

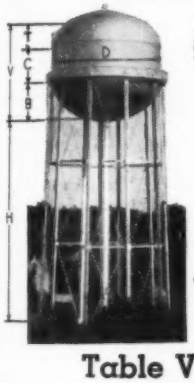
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 5	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



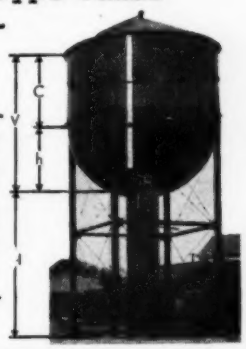
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....
50,000	22	13 2	19 4	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 8
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks



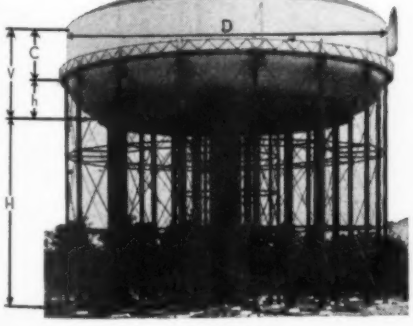
Capacity in U.S. Gallons	D	B	C	T	V	H
50,000	22'-0"	5'-10"	9'-4"	4'-4"	19'-6"	
75,000	26'-0"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	34'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	36'-0"	9'-0"	12'-11"	6'-9"	28'-8"	Built
250,000	40'-0"	10'-4"	11'-7"	7'-6"	29'-5"	
275,000	40'-0"	11'-11"	13'-9"	7'-6"	33'-2"	to
300,000	40'-0"	8'-7"	17'-11"	7'-6"	34'-0"	
350,000	44'-0"	14'-8"	13'-10"	8'-0"	36'-6"	Order
400,000	46'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	50'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000	55'-0"	14'-4"	14'-0"	10'-0"	38'-4"	
750,000	60'-0"	15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	21'-8"	15'-9"	11'-0"	48'-5"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	
25,000	15	14	7	19	11	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
30,000	17	12	7	19	0	
40,000	19	13	1	20	6	
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks



Capacity in U.S. Gallons	Tank Diameter (D) when h = 10' 0" and V=20' 0"		V=25' 0"		V=30' 0"		V=35' 0"		H
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built
1,500,000	115	2	102	9	93	9	86	8	to
2,000,000	132	8	118	5	108	0	99	11	Order
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Heights ft.	in
50,000	20	21	6
60,000	22	21	6
75,000	24	22	6
100,000	26	25	6
150,000	30	28	9
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	0
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	9

CHICAGO BRIDGE & IRON COMPANY

Chicago 4.....2198 McCormick Bldg.
New York 6.....3390-165 Broadway Bldg.
Cleveland 15.....2262 Guildhall Bldg.
Los Angeles 14.....1455 Wm. Fox Bldg.
Birmingham 1.....1586 North 50th St.
Atlanta 3.....2181 Healey Bldg.
Tulsa 3.....1646 Hunt Bldg.
Houston 1.....5615 Clinton Dr.
Philadelphia 3.....1644-1700 Walnut Street Bldg.
Washington 4.....703 Atlantic Bldg.
San Francisco 5.....1283-22 Battery St. Bldg.
Detroit 26.....1551 Lafayette Bldg.

Plants in Birmingham, Chicago and Greenville, Pa.

In Canada: Horton Steel Works, Limited, Fort Erie, Ont.

Above: A 1,500,000-gal. radial-cone bottom tank at Indianapolis, Ind. This tank has cylindrical columns. The tank shown at the right of the table is a 1,500,000-gal. radial-cone bottom tank with a balcony and structural columns. It is located at Manitowoc, Wisconsin.

WE design, fabricate and erect Horton elevated water storage tanks, flat-bottom steel reservoirs, Waterspheres, gasholders, pressure vessels and other steel plate work. Water works engineers and municipal officials planning modernization programs or extensions to existing water distribution systems are invited to write our nearest office for estimating figures on the installation of these products.

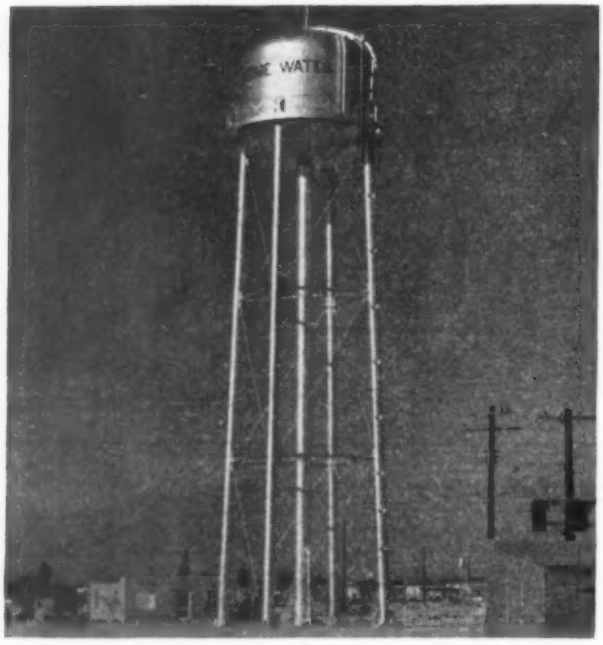
Horton Radial-Cone Bottom Tanks

The radial-cone bottom design enables us to build large-capacity elevated tanks with a low range in head. Tanks of this design are built in capacities up to two million gals. with a range in head of only 25 ft. The radial-cone design can also be used economically where a range of 30 to 50 ft. is permissable. This design can be varied in appearance by the use of a cone, dome or ellipsoidal roof. The table below shows standard sizes for radial-cone bottom tanks.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′

A booklet is available, showing various sized radial-cone bottom tank installations.



Horton Ellipsoidal-Bottom Elevated Tanks

Ellipsoidal-bottom tanks have a relatively large diameter and shallow depth which gives the structure pleasing proportions and reduces the variation in pressure between the upper and lower levels. They are built of welded construction with ellipsoidal roofs and cylindrical columns. Riveted designs with structural columns are also available. The riser on an ellipsoidal-bottom tank is connected directly to the tank bottom. There is no expansion joint to require inspection or packing. In nothern climates the diameter of the riser is increased to prevent freezing.

The Horton ellipsoidal-bottom tank shown at the left holds 50,000 gals. It is located at Tuscon, Arizona.

WELDED ELLIPSOIDAL-BOTTOM TANKS

Capacity U. S. Gallons	TANK DIMENSIONS Diam.	Shell Height	Depth in Roof and Bottom	Range
50,000	22′0″	11′0″	4′0″	19′0″
60,000	24′0″	11′0″	4′0″	19′0″
75,000	26′0″	11′0″	5′0″	21′0″
100,000	28′0″	14′0″	5′0″	24′0″
125,000	30′0″	16′0″	5′0″	26′0″
150,000	32′0″	15′0″	6′0″	27′0″
200,000	36′0″	16′0″	6′0″	28′0″
250,000	40′0″	15′0″	7′0″	29′0″
300,000	42′0″	17′0″	7′0″	31′0″
400,000	46′0″	19′0″	7′0″	34′0″
500,000	50′0″	19′0″	9′0″	37′0″

HORTON ELEVATED WATER STORAGE TANKS
. . . WASH WATER TANKS . . . FLAT BOTTOM STORAGE TANKS . . .

CHICAGO BRIDGE & IRON COMPANY

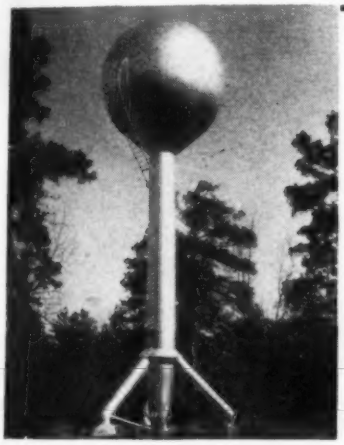
Chicago 4.....2198 McCormick Bldg.
New York 6.....3390-165 Broadway Bldg.
Cleveland 15.....2262 Guildhall Bldg.
Los Angeles 14.....1455 Wm. Fox Bldg.
Birmingham 1.....1586 North 50th St.
Atlanta 3.....2181 Healey Bldg.
Plants in Birmingham, Chicago and Greenville, Pa.

Tulsa 3.....1646 Hunt Bldg.
Houston 1.....5615 Clinton Dr.
Philadelphia 3.....1644-1700 Walnut Street Bldg.
Washington 4.....703 Atlantic Bldg.
San Francisco 5.....1283-22 Battery St. Bldg.
Detroit 26.....1551 Lafayette Bldg.
In Canada: Horton Steel Works, Limited, Fort Erie, Ont.

Bins, Storage
Breeching, Steel
Chutes, Steel
Filtration Plants
Flumes, Iron and Steel
Gas Holders
Hoppers, Steel
Penstocks
Pipe, Riveted Steel
Pipe, Welded Steel
Pressure Vessels, Welded
Reservoirs, Steel
Receivers, Air
Smoke Stacks
Standpipes
Steel Plate Work
Tanks, Elevated Steel
Tanks, Storage
Tanks, Surge
Tanks, Washwater

Elevated Hortonspheroid

In addition to our standard Horton radial-cone bottom tanks and ellipsoidal-bottom tanks we also design, fabricate and erect structures of special design to meet specific municipal requirements. The 1,000,000-gal. elevated Hortonspheroid shown at the right is located at Jonesboro, Ark. We will be pleased to discuss the advantages of various designs of elevated tanks with you—without obligation.

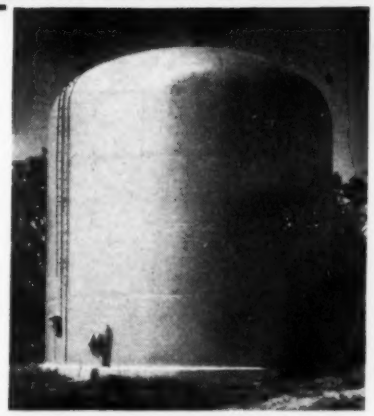


The Watersphere

These modern, streamlined elevated water storage tanks consist of a sphere supported by a single column. Waterspheres ranging in size from 40,000 gals. to 250,000 gals. have been built. The Watersphere at the left holds 60,000 gals. and provides gravity water pressure for a portion of the water supply system at Gadsden, Alabama.

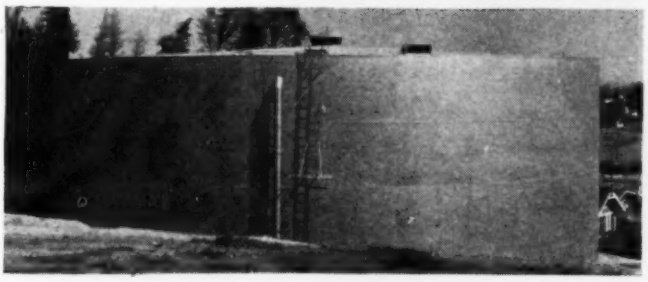
Flat-Bottom Water Storage Tanks

We build flat-bottom water storage tanks in any diameter and height to meet your requirements. The flat-bottom tank shown at the right holds 25,000 gals. and has an ellipsoidal roof. It is used for water storage at Kent, Ohio.



Hortonspheres, Sewage Gas Holders

Sewage disposal plants have proven that the utilization of gas produced in digesters for power and heat is an economy-wise practice. Hortonspheres are used to store the excess gas for use when gas production is low. The Hortonsphere shown at the left is used for this purpose at the sewage disposal plant at Beaver Dam, Wisc. It is designed for 40 lbs. per sq. in. pressure.



Horton Steel Reservoirs

In hilly areas natural elevations can sometimes be used to provide gravity water pressure in a municipal water supply system. We build flat-bottom steel reservoirs for this type of service. These reservoirs may be of standard design or built specifically to meet your requirements. The reservoir shown above holds 1,000,000 gals. and is located at Hermosa Beach, California.

HORTON ELEVATED WATER STORAGE TANKS
. . . SEWAGE GAS HOLDERS . . . ELEVATED HORTONSPHEROIDS . . .

R. D. COLE MANUFACTURING CO.

Est. 1854

Tanks, Towers, and Steel Plate Work

NEWMAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

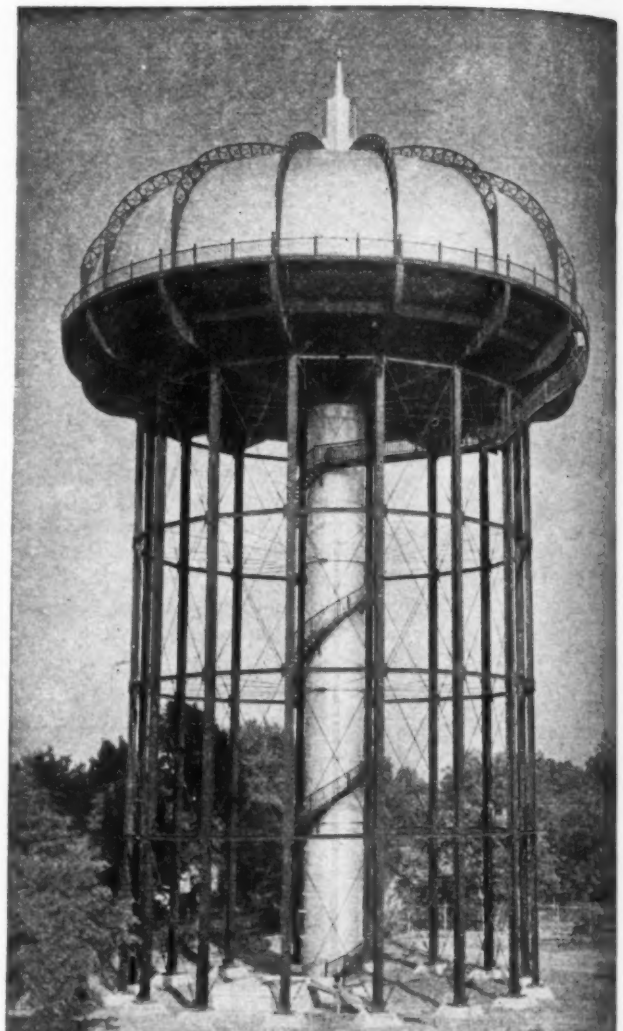
All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service



1,000,000-Gallon "Cole-Shallow Depth" Tank

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ELEVATED STORAGE

The Value of Elevated Tanks on Water Supply Systems

By CHARLES BROSSMAN

Late Consulting Engineer, Indianapolis, Ind.*

In many cities the advantages of elevated water storage has been recognized, usually with considerable return on the investment.

On closed water systems without some form of storage facilities, where centrifugal pumps are in service, the pumps are usually installed large enough to take care of peak loads. It is quite evident that, with a pump available to take care of such peak loads, on the lighter loads (especially at night), the pump drops off greatly in efficiency, as does the motor. Such day in and day out waste of power mounts to an appreciable sum as time passes, until losses overbalance the costs of providing storage on the system —in instances many times over.

For instance: Assume a modern pump operating at full load efficiency of 70%, and motor at 90%. The unit will give a combined efficiency of 63%. This pump on the lighter loads, with a drop in efficiency of 50%, and the motor at 80%, gives a combined efficiency of only 40%, a difference between the two of 23 points.

It is readily realized that with such a condition recurring daily, the power consumption may be surprisingly increased for the year. Not alone such current waste, but if power is being purchased with a maximum demand charge on the motor size the rate will be increased due to this factor, for the reason that the pump motor must be large enough to take care of the peak load. On the other hand, an elevated tank will allow more uniform pumping, the pump and motor size can be reduced, thereby reducing the costly demand factor.

Another very evident disadvantage is that pressure is lost immediately whenever pump service is interrupted for any of several possible reasons. In case of fire such is disastrous. In any case, the public served is paying a penalty in insurance rates where pressure storage is not available on the system.

Furthermore, another advantage from elevated storage is that any pump on the line can be used at its maximum output, and with a correspondingly maximum efficiency. Pumps, therefore, can be purchased for use with elevated tank service over their maximum range of efficiency, with assurance that such efficiency can be realized in every day operation.

Another advantage is uniform pressure. With an elevated tank, automatic regulating control is available, whereby the tank variation in head may be kept within a few feet, thereby giving absolutely uniform pressures under all conditions of draft on the system. Particularly advantageous are elevated tanks in outlying districts, to reduce pumping costs and render better service pressures and flow. It is hardly necessary to indicate that more water will be used, in consequence, and a higher income enjoyed by the water utility.

In considering the values of elevated tanks for water storage it is apparent that there are a number of advantages.

Power Saving Case Records

The first advantage, that of saving in power cost, is the most appealing and in practically all cases a considerable saving in power will result. As a concrete example we may take the experience of a small plant in a town of 1,100 with which the writer is very familiar.

The Town of Albion, Indiana, had a water consumption of approximately 50,000 gallons per day. In this case an elevated tank was installed, the total cost of the tank being approximately $7,200.00. The power used before installing this tank, on the closed system, was approximately 1 KWH for 530 gallons; after the tank was installed, pumping was approximately 1 KWH for 1,050 gallons. This proved a spectacular attainment of cutting power consumption in half, but there are other Albions scattered over the country.

In this particular case, the tank will be paid for in less than 15 years by the saving in power bills alone. If the rate of consumption increases the time will be shorter, of course.

Here is a point of considerable interest in this case. Albion has its own generating plant, and the total cost of power is considered at 3c per KWH, including all costs. A careful check on all costs and power used still indicates the investment well justified. One reason is found in the fact that fire protection is now supplied with the small 200 G.P.M. pump and the large steam fire pump is no longer maintained as a ready to serve unit with fire in the boiler. Steam, however, can be had from the municipal power plant in case of necessity, and the pump is still available.

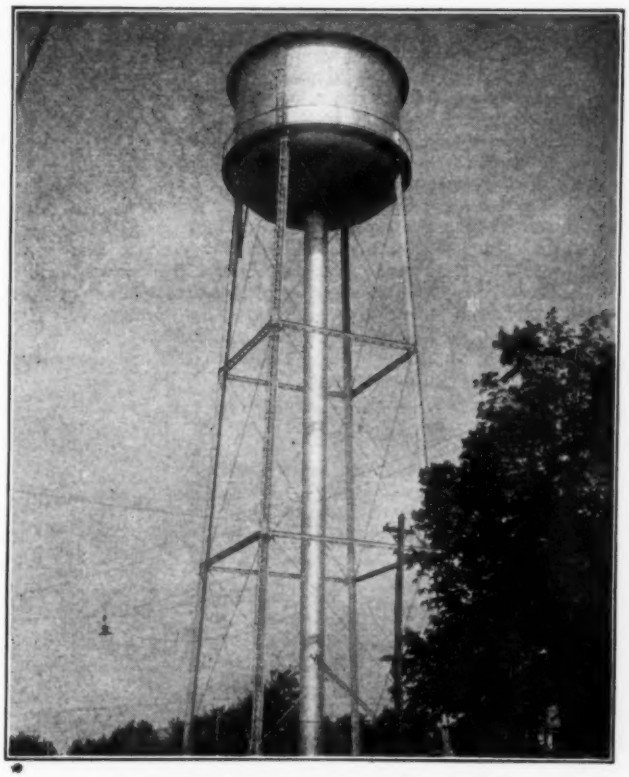
Another example is found in the City of Goshen, Indiana, where there has been installed a 500,000 gallon tank. The old plant was steam driven. About six years ago, the city installed a modern Diesel lighting plant, but only two of their deep well pumps were electrified at that time. The boilers had to be kept going at all times in the old steam plant, in order to have available suitable fire protection. In this case, a P.W.A. loan made it possible for Goshen to electrify its water works system. The city now has eight electric driven deep well pumps, and a new half million gallon tank. The loan by P.W.A. was negotiated on the basis of anticipated savings resulting from abandonment of the steam plant.

The cost of pumping for the old system on which boilers had to be kept up at all times, was given at approximately 8.3c per thousand gallons, which of course, was high, but the equipment was old, and used air lift pumps and double pumping, except for the two electric driven pumps.

It is estimated that the actual electrical pumping cost would be in the neighborhood of 1.2c per thousand gallons, and total cost at 2.2c per thousand. To take advantage of the potential saving (about 6c per thousand) an elevated tank had to be installed.

The old standpipe was not adequate for the demands, as the upper portion of this standpipe did not store very much water. The new elevated tank, of one-half million gallons, was installed some distance from the plant and on the opposite side of the city.

The entire pumping equipment is automatically controlled, there



The 50,000 Gal. Tank of Albion, Ind. Will pay for itself in less than fifteen years.

* Excerpts from a paper written by Mr. Brossman shortly before his death. It was presented before the Indiana Section of A.W.W.A.

being two automatically controlled pumps at the tank site (about 1.5 miles from the main station), and six automatically controlled deep well pumps at the main station, each pump having a capacity of 500 G.P.M. Any pump can be manually started or stopped by push button control from the main plant.

Results at Goshen

Merle J. Miller, Superintendent and Manager of the Goshen plant, has made it possible for me to take the following from his report on the Goshen betterments.

"With a stand-pipe of the small capacity that we had previous to the erection of our new elevated tank, our water circuits were only fairly stable, but since the additional storage capacity has been added to our system, it has made a wonderful change in our water pressure charts as there is more cushion and no surge anywhere along the line. A number of charts taken at the elevated tank location have been absolutely perfect from the standpoint of surges or variation in pressure. We found before, especially with the steam pumping equipment, that we could detect each pulsation of the steam pump, as our standpipe capacity, at that time, was not enough to cushion the whole system properly. Comparing the old system as against the new system for uniform pressure, there is a vast difference. From the new system, if given any attention at all, we get a chart of uniform pressure, with as little variation as one pound.

"We also find a marked difference in the circulation of the water in districts where we had frequent complaints during the warm summer months against the warm stagnant water."

From the foregoing, it will be seen that in any plant that does not have an elevated tank, or if they have a standpipe of very small capacity, with very little water available in the upper section, the modern type of elevated tank, with all of the storage at the proper level, will almost invariably result in a financial saving, as well as give the other advantages which accrue to it.

One of the Two 1,500,000 Gal. Tanks of Indianapolis
A leafy green and silver structure which constitutes a study in "neighborhood-treatment" of water towers.

Concerning Fire Protection Requirements

The relation of the elevated tank to fire protection is one of the important factors that should not be lost sight of. Modern elevated tanks, as compared to old standpipes, are much different for the available capacity for fire fighting facilities, as credit for water in a standpipe is only allowed for the top sections. Modern tanks, as now designed, keeps the water level to within a few feet variation, dependent more or less upon type of regulating control on the electric pumps.

Fire flows should not be confused with the total daily flow or capacity. For instance: if a town has a total available supply and storage based on a 24-hour period the fire flow will usually be based on a 5-hour flow for communities of 2,500 and less, which means that they will need 4.8 times the average consumption capacity as storage capacity for fire. For cities above 2,500 the multiplier will be 2.4 times for fire storage, as against consumer use storage. Such is based on a requirement of capacity for not less than a 10-hour period of continuous fire flow.

The fire flow requirements for average cities are given by the Underwriters, as follows:

Population	Required Flow (G.P.M.)
1,000	1,000*
2,000	1,500*
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000 *

* For 5 consecutive hours; all higher flows for 10 consecutive hours.

Therefore, in selecting the tank the fire flow for the period required, according to population, is the primary consideration. To this must be added the domestic consumption.

This amount indicated is then balanced against the available low lift capacity of the pumps, such as wells or filters, also the ground storage capacity. The total low lift and ground storage capacity is then determined.

The second step is to figure the high lift pump capacity and the elevated storage capacity.

After these two quantities are known, they are compared to the required fire flow and domestic flow over the 5 or 10-hour period, as the case may be. This will then give the ideal condition in installed pumping capacity and tank size.

In case these conditions are not met, if there is a deficiency in pumping capacity or storage on either the low lift and ground storage or high lift and elevated storage, this deficiency will be taken into account in the making of rates.

It should be clearly kept in mind that the total 24 hours available capacity is not what is considered by the Underwriters. They base the capacity wholly on the fire flows listed for the period of hours noted.

Concerning Tower Heights

The matter of pressure from elevated tanks should not be lost sight of, as various pressures are required for certain types of buildings, according to the size town and construction therein.

One of the outstanding tank installations in this country, is that installed by the Indianapolis Water Company.

This large tank is located in the eastern section of Indianapolis, which is approximately 100 feet higher than their main pumping station. With this long line of pipe, and the ensuing friction losses, pressures were previously very low in this district. It was decided, after considerable study of ground as elevated storage, to erect an elevated tank with 1,500,000 gallons capacity to serve the approximately 64,000 people in this district. This tank has resulted in great improvement in pressure and supply, with an ensuing satisfaction to the water consumers.

This tank is the largest one in the state of Indiana on a public water supply, the tank being 72 feet to the bottom, and with this large capacity, having a range of only 25 feet between the upper and lower water levels. As the result of benefits noted the Water Company is undertaking a tank of like capacity in another section.

In conclusion, I would state that there are many plants on which a study of water storage as well as pump efficiencies connected therewith, would result in a marked saving in the operation of such plants.

CENTRIFUGAL PUMP PECULIARITIES*

By ROBERT W. ANGUS
Consulting Engineer, Toronto, Ont.

PRACTICALLY all pumping units now being installed in water works plants are composed of centrifugal pumps driven by electric motors, steam turbines or internal combustion engines, and few plants today use reciprocating pumps. Experience with centrifugal pumps has now been sufficiently extensive for operators to know many of their peculiarities; yet there are features connected with their use that are worthy of review.

Setting of Pump

The setting of the pump is perhaps one of the most important matters, as it may easily account for any later defective operation. It is, of course, well known that the pump should be set as little above the well level as possible, and it is usually preferable to have it below this level (except for the difficulty of unwatering it) if for no better reason than ease of priming and freedom from the foot valves on the suction line. That the pump is unduly sensitive to suction conditions is a matter of general experience, and long and crooked suction piping is to be avoided.

The author has made tests on the effect of foot valves, which showed that resistance in these might cause a high vacuum at the suction flange of the pump and a corresponding decrease in discharge. [*Jour. AWWA*, 37:70 (1945)]. High-suction vacuum naturally induces air leakage into the pump through the glands, and also releases whatever air there is in the water being pumped. In order to investigate the effect of air leakage, a number of experiments were run on a 4-in. pump, in which various volumes of air were admitted into the suction pipe after carefully sealing the glands so that leakage was practically stopped there.

In this pump the percentage decrease in discharge at a given head was roughly proportional to the percentage, by volume, of air admitted, so long as the latter remained below about 1.5 per cent (see Fig. 1); but thereafter the water discharge fell off very rapidly until there was a decreased discharge of over 40 per cent when 4 per cent of air, by volume, was admitted. This merely confirms the well-known fact that at low suction lifts, and consequently low air inlet leakage, the exact elevation of the pump is not so important. There is a critical elevation for each pump and condition, however, and if this is exceeded the loss of water increases at a rapid rate. Clearly the height of the pump above the well level should be kept substantially below this critical elevation.

Specific Speed

Fortunately the importance of this matter is now recognized by the pump builders, and they have found that for each head, discharge and speed there is a maximum height above the well at which each pump should be set. These three quantities are combined in a formula for "specific speed" which is defined by:

$$\text{Specific speed} = N \times \sqrt{G/H^{0.75}}$$

where N is the revolutions per minute, G is the discharge in U. S. gallons per minute and H is the head in feet.

Pump builders have co-operated in connecting the specific speed and head with the maximum allowable suction lift, basing their conclusions on laboratory tests and on experience with pumps which they have installed. Through the Hydraulic Institute they have given these maximum elevations in the form of diagrams, separate ones being used for single-entry pumps, for double-suction single-stage pumps, etc.

As an illustration, there are four double-suction single-stage raw water pumps at the Victoria Park pumping station, Toronto, Ont., rated at 24, 30, 48 and 60 mgd., respectively, all of them for 9-ft. suction lift and for a total head of 82 ft. The two larger pumps operate at 750 rpm., and if this speed had been adopted for all four pumps, their specific speeds and maximum suction lifts, including velocity head and friction in the suction pipe, would have been as shown above in the Institute's chart.

Size of pump, mgd. (U. S.)	24	30	48	60
Specific speed at 750 rpm	3545	3970	5010	5610
Maximum allowable suction lift, *ft*	18	15	5	..
Necessary suction pressure, *ft*	..	..	..	5
Specific speed at 500 rpm	..	..	3340	3749
Maximum allowable suction lift, *ft*	..	..	20	17

Since the velocity heads in the two larger pumps are 2.3 and 2.1 ft., respectively, and since friction must be allowed for, it is clear that, while there is a margin on the two smaller pumps when run at 750 rpm., the two largest pumps could not be run at this speed and had to be changed to 500 rpm., which is the next available speed.

Setting pumps too high not only causes them to lose capacity, but also means noisy operation and cavitation, which is frequently destructive. As the capacity of a pump at fixed speed is gradually increased by lowering the discharge pressure, a point is finally reached where the characteristic curve is nearly vertical, which point naturally corresponds to the limiting output of the pump. Cavitation and noise are present at such a discharge (and in its vicinity) and the higher the suction lift the lower this limiting output is. It is to avoid too close an approach to this point that the charts reproduced have been made. Noise in a pump operating near this limiting point may often be stopped by the admission of a very small volume of air to the suction pipe.

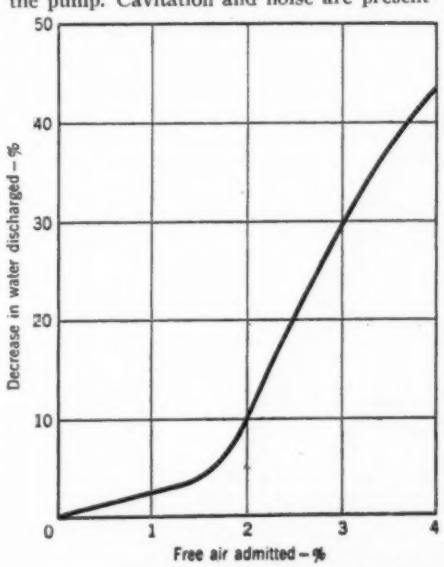


Fig. 1—Decrease in Discharge of Centrifugal Pump Due to Admission of Air Into Suction Pipe in Various Amounts.

[Ed. Note—Indeed an interesting and illuminating statement in view of the generally held misconception that cavitation, with its noise of pebbles or buckshot passing through the centrifugal casing, is due to air within the casing. On the contrary, it appears that the noise is due to partial vacuum within the casing which is relieved by admitting air.]

Power Failures and Water Hammer

Power failures on motor-driven centrifugal pumps present some problems. A check valve is usually placed on the line close to the pump, and if this acts slowly there is backward flow through the pump which reverses its direction of rotation unless specially prevented. If the check valve does act rapidly, however, water-hammer pressures are often excessive, resulting in damage to the plant. A number of cases of the latter have recently come to the author's attention.

Water hammer, contrary to a common belief, is also often dangerous in low-head pumping. The author made some tests on a 12-in. pump working against a 55-ft. static head, with a discharge line only about 350 ft. long, and recorded the pressures with a Crosby indicator with a 30-lb. spring. When the switch was opened the pressure drove the indicator pencil off the top of the drum, indicating a pressure of more than 60 psi., and the first pressure wave measurable showed 50 psi. or a 115-ft. rise. As stated, this was a short line and the pipe velocity was under 4 fps. However, in another case where the static head was 40 ft. and the line was over 2,000 ft. long, the pressure rose to 83 ft. with normal pipe velocity of slightly over 7 fps. In both cases the pressure rise was high enough to cause some anxiety, which was further aggravated in the first case by the noise and shock plainly observed at the pump, while in the second case there was *no* apparent shock on the system. In the first case, the maximum pressure rise occurred 2.6 seconds after cutting off the power, whereas it took 13.0 seconds in the latter case.

Short lines are sometimes more dangerous than long ones, because in the latter the water takes an appreciable time to slow down before coming backward, thereby giving the check valve time to close *gradually* and prevent any real reverse flow of the column. In short runs of pipe the water column reverses in much less time, as the above measurements show, and

actually *before* the check valve has had time to close. Thus the water gains a high backward velocity, suddenly closing the check valve with a slam, and producing high pressures. The maximum pressure rise, in feet, reaches about one hundred times the velocity of the water in the pipe at the time the valve suddenly closes.

Air Chambers vs. Properly Closing Check Valves

Sometimes an effort is made to decrease the danger by using an air chamber, but this is far from the best method and does little good unless the chamber is placed on the line near the pump and has a large short connection with the pipe. Air chambers connected to the line with a fairly long branch pipe are of little value and, of course, any virtue the device has will be lost unless there is a good volume of air in the chamber under normal conditions. A well-designed check valve, with a proper controlling mechanism which permits the greater part of the closure to be rapid and the latter part gradual, offers a good solution, and a number of such valves are now on the market. It is a fact that unless the pump is equipped with a heavy flywheel, as is sometimes the case, the pump will often run backward before the check valve closes, but, in general, the reverse speed is not over 20 per cent higher than normal running speed and is not dangerous from that standpoint.

In many installations reverse rotation of the unit causes little difficulty, but where sleeves are screwed on the shaft and pass through the packing gland, the builder usually makes the thread so that during pumping the tendency is to tighten the sleeve against the impeller. If the glands are tight, then when the pump runs backward the sleeves may unscrew, and cases are not unknown where the pump has been damaged by breaking off the bearing bracket. With the sleeve unscrewed the impeller is not properly restrained from moving along the shaft and this further increases the danger of damage.

Pumping Plants

There are some unusual installations, one of which may be mentioned as an illustration (see Fig. 2). A very large size pump with a vertical shaft was set up with 40 ft. of vertical discharge pipe followed by a long horizontal line. The pump was nearly 20 ft. below the water in the well so that no priming was required, but there were nearly 800 ft. of horizontal suction (intake) pipe in which the velocity was 5.9 fps. at steady operation. It was inconvenient to place the discharge valve close to the pump, and it was actually installed just beyond where the horizontal and vertical pipes joined. There was no valve of any kind on the suction side. In the installation shown diagrammatically in Fig. 2 the distance (A) was nearly 20 ft.

Following common practice, the motor switch was thrown in with the discharge valve closed, and just as the valve started to open when the pump was up to speed, a pressure shock cracked the pump casing. This might have been foreseen, because, when the pump was shut down with discharge valve closed, water in the vertical discharge pipe quickly fell to the well level, leaving a space filled with air in the discharge line between the well level and the valve. On starting the pump against the closed valve the air was compressed to about discharge pressure, and as the valve

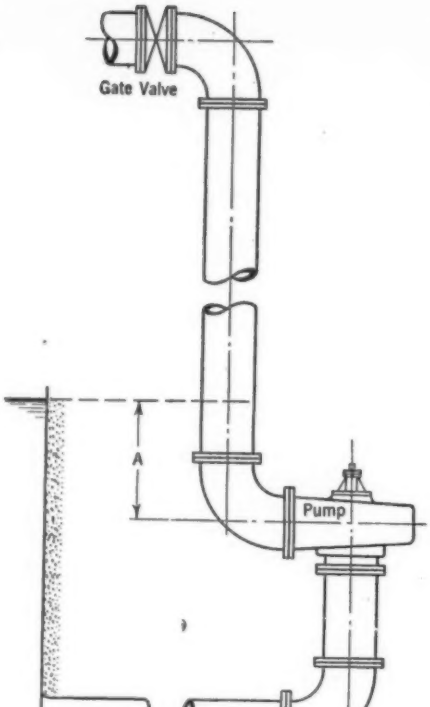


Fig. 2—Unusual Pump Arrangement That Resulted in Heavy Water Hammer Pressures Until Vacuum Pump Was Installed to Exhaust Air from Discharge Pipe and Fill It with Water Before Starting Up.

began to open the air rushed out of line, allowing the water to reach full velocity in the vertical pipe. As the front of this water column reached the partly open valve the velocity was largely extinguished and a heavy water hammer pressure resulted. Since it would have been very expensive to lower the discharge valve, the only remedy was to put in a vacuum pump and exhaust the air, in order to fill the line with water before starting up.

The long horizontal suction pipe greatly complicated the problem, for the water would be drawn from the pump end of it before the column could be sufficiently accelerated to supply the demand, and water hammer pressures would be set up in the pump from this cause. A well should always be close to the pump (or the pump located close to the well) to supply the water demanded while that in the intake line is being brought up to running velocity.

Where several pumps are to work in parallel on the same line, their characteristics should be given careful consideration, otherwise their actual output may fall far short of the sum of their individual deliveries. In Fig. 3 are shown the characteristic curves of two actual pumps, A and B, in the same station, their individual normal operating points being indicated by G and J. If these two pumps are thrown on the line at one time their combined characteristic is shown by the plain curve found by adding the discharges of A and B at the same pressure in each case. The static head, corresponding to the tank level, is shown at D, and the curve C indicates the dynamic head to be pumped against, the vertical distance between D and C corresponding to the resistance loss for the corresponding discharge.

It is to be noted that, while the sum of the separate discharges at rated heads is 180 per cent of the discharge of the larger pump, yet when both are put on the line at the same time the combined discharge at F is only 133 per cent of that of the larger pump, because of the increased pressure. Where the individual characteristic curves are flat this decrease is greater than with steep curves, because a slight increase in pressure corresponds to a large decrease in discharge, but, on the other hand, a pump with steep characteristic at the normal output point has a rapid decrease in pressure for discharge above normal, so that other circumstances must be taken into account.

Propeller-type Pumps For Low Head Duty

Propeller-type pumps are being introduced to a fairly large extent to cover the field where the head is low and the discharge is large. Centrifugal pumps are used in this service, but must be run at slow speed and involve the use of a speed reducer or an expensive and bulky motor, whereas the propeller-type pump is relatively small and may be run at the speed of the ordinary motor. Its field of service is for drainage and sewage work and for pumping water up to water works filters, but the same type of pump is also used for deep wells because its small diameter enables it to be fitted inside ordinary pipe casing.

As so far developed, these pumps have the undesirable characteristic forms of curves, where the head and power at zero discharge and at full speed are higher than and sometimes twice as high as, the corresponding quantities at rated discharge, and the curves generally have the reversed form. Usually the pressure is not high enough to cause any trouble, but the high power means a correspondingly large torque on the motor, which the latter may not be able to produce. Therefore either special starting devices are necessary or the pump must not be brought up to speed with a closed discharge valve. With a check valve on the discharge and an open gate valve, the head developed cannot exceed the back pressure from the line, and this is one effective method of starting that is used. Also a bypass is sometimes arranged around the pump, having a valve which may be opened so as to allow some water to flow through the pump, thus avoiding the zero discharge condition.

Deep Well Pumps

Deep well pumps must be as small in diameter as possible so that they will fit into the well casing, and for that reason they approach the axial-flow type with relatively small head per stage, although the high motor speeds somewhat compensate for this. However, for the higher heads many stages are used, and guide vanes are placed between each pair of impellers. Both open and closed impellers are used, but the latter are the more common. The driving motor is often placed at ground level, and the pump is usually submerged in the well water to avoid priming, but since these wells are sometimes 200 ft. deep, the driving shaft is long and has to be guided at various points at which rubber-lined guide bearings are often used with water lubrication.

Some builders, such as Byron Jackson, couple the motor to the shaft as in ordinary installations, and the motor is there-

fore submerged in the well water and often is actually located *below* the pump.

Power failures on these pumps, where the vertical pipe is long, result in back-flow through the pump and cause the pump to run in the reverse direction, but most pumps of this type are designed to withstand this without damage. However, the surges in the pipe during reverse flow of the water affect the pressures in the pump to such a degree that open impellers may be forced to pound down against the casing and wear somewhat rapidly. Some builders arrange a ratchet or a brake on the pump shaft to prevent the latter from turning backwards.

Where both motor and pump are submerged and completely enclosed, it is difficult to tell whether the electrical connections are such that the pump is running backwards, and in three-phase circuits it is well known that the connection for forward rotation can only be found by trial. If it is impossible to tell by visual inspection whether the pump runs backwards or not, about all that can be done is to read the discharge gage pressure; if this pressure at no discharge is very much below the normal working head on the pump, the motor and pump are, in all probability, running backwards.

Miscellany and Summary

Noise accompanied by cavitation damage in pumps is frequent if the pumps are set high above intake water level. The same results are noticed when the discharge is low, due to either reduced speed or increased head. Foot valves and strainers on the suction inlets may also induce these troubles and should be avoided where possible.

Occasionally cavitation has seriously damaged impellers in less than two years but it is often quite possible to build up the damaged places and completely restore delivery and efficiency. Frequent inspection is necessary. In one case an impeller was covered with a thick coating of slimy material which decreased the capacity considerably. This pump was used partly for refilling the coagulating basins and was designed for about a 26-ft. head. When the water was low in the well its capacity fell off. A number of operators have found that high suction lift decreases output.

Occasionally, noise in the motor gives the impression that the pump is at fault.

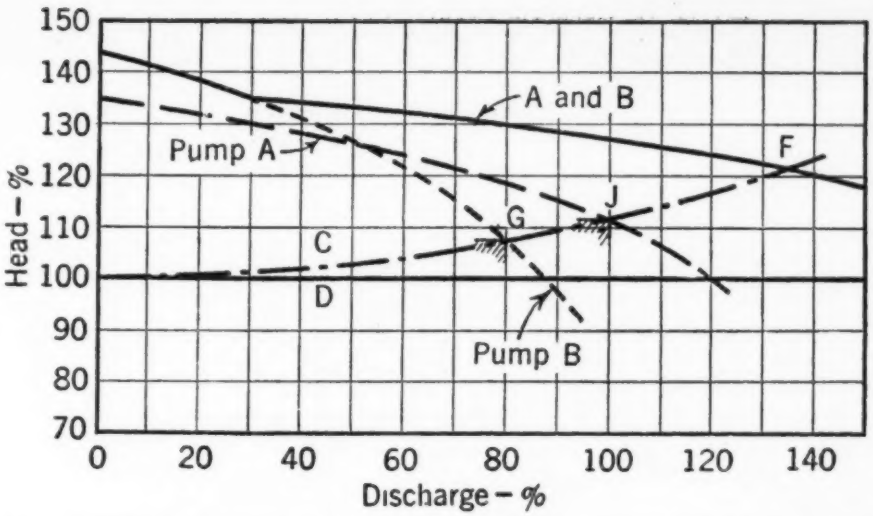


Fig. 3—Characteristic Curves of Two Pumps Operating in Parallel in the Same Station and Discharging Through a Common Header.

Noise in the pump may frequently be greatly reduced by admitting air to the suction side, but this must be carefully controlled, as the capacity falls off rapidly as the admitted air increases. In some tests of one pump 4 per cent of air by volume reduced the capacity nearly 40 per cent.

Putting several pumps in parallel on the same line decreases the capacity of each in a way that varies with the pump characteristics. There is, of course, increased friction in the discharge lines when more water is put through; and, as this increases the head on the pump, there will be a corresponding decrease in discharge.

There is an objection to a common suction header for several pumps, as air may leak through the glands on the idle pumps and interfere with those running. The suction pipe of each pump should run direct to the well as an independent line.

Water hammer and pressure surges are common on lines having centrifugal pumps. Frequently a pressure surge lasting a short time occurs when a pump is put into service. Power failures cause extensive pressure oscillations which have been greatly reduced by special types of check valves with a controlled time of closure. Air chambers are not as satisfactory.

The shape of the profile of the discharge main greatly affects water hammer in the line after power failure. In the 48-in. line in Toronto there is a point where the pressure drops much below atmospheric when power fails, and observations agree with the theory that the water column actually separates at this point. The use of a specially controlled check valve with 4-in. bypass has prevented a dangerous pressure rise when the columns re-unite; the purpose of the bypass is to fill enough of the space with water before the velocity of the returning column from the reservoir becomes high enough to cause damage when it re-unites with the part of the column at the pump end. The actual maximum pressure rise is only about 35 per cent and is reached in about 50 seconds where the pipe velocity is low. The pump is about 4,300 ft. from the breaking point of the column and nearly 8 mi. from the reservoir.

Reversal of pumps after power failure has often been observed, but with no harmful results to the motors. A case has been reported, however, of an engine driving a centrifugal pump being damaged by running backward.

Aside from ordinary wear, the mechanical difficulties with pumps are not serious. Some pumps have excessive end thrust, and where this is taken up by ball bearings, the latter run hot. Over-lubrication is known to increase the heating. Bearings are easily cooled with a small stream of water. Hydraulic balancing of end thrust is satisfactory where the pump is running under normal conditions.

HOW TO BEND PIPES

TO bend steel pipes, fill with dry sand and plug the ends. Heat to a red heat in the localities to be bent and then bend. *Be sure that the sand is dry.* Where bends are slight, it is often unnecessary to use sand. The object of sand is simply to keep the sides of the pipe from collapsing, or to prevent reduction of flow area. If wet sand is used, and if the ends are plugged, the pipe may burst when heated, due to the steam pressure generated.

For the smaller pipes instead of sand resin is good. There is, however, a "right way" and possibly several wrong ways to use resin. An example of a wrong way was recently brought to my attention where the mechanic filled the pipe with resin, plugged the ends, and heated the pipe at the place where he wanted to bend it. He watched for a "red heat" just as he would had he filled the pipe with sand. The result was a violent explosion.

To use resin correctly, pour it into the pipe molten and allow it to cool and harden. As soon as the resin is hard, bend the pipe cold. Don't heat it. Then after the pipe is bent, heat the pipe all over sufficiently to melt and remove the resin.

Equal results may be secured by using lead instead of resin. I have been told that on cold days water has been used also.

Many excellent mechanical devices are on the market for bending pipe. To bend large, stiff pipe slightly (and inexpensively), there is nothing handier or more efficient, in my judgment, than a hydraulic pipe bender driven by a hand pump.

AUTOMATIC OPERATION OF CENTRIFUGAL PUMPS

A Discussion of Fundamentals of Automatic Control

By W. D. HAENTJENS
Engineer, Barrett, Haentjens & Co., Hazelton, Pa.

THE purpose of automatic pumping is, in most cases, the achievement of more economical operation through the elimination of an attendant. At times, the purpose is greater safety of operation.

In the simplest case of automatic pump control, that is, pumps operating with a positive head on the suction, no special equipment except float switches and automatic starters is required.

Pumps operating with a suction lift can be equipped with a footvalve which keeps the pump filled with water between runs. Automatic control here can be the same as that for pumps operating with a head on the suction. However, the use of a footvalve results in somewhat unreliable control. There are several objections to the use of a footvalve; (1) the pump is unprotected from water-hammer and failure of the pump casing may result; (2) the footvalve may leak, thus leaving the pump without water. When the pump is started, damage would undoubtedly result to the pump; (3) friction in the footvalve results in an increased suction lift.

Components of Automatic Control Systems

A brief description of the operation of a few of the components of an automatic control system (Fig. 1) is perhaps in order here.

I. Check Valve with Switch—The check value is always placed on the discharge end of the pump. To the flap of this valve is attached a switch. This switch may be one such as a lever-operated contact switch or a Mercoid switch. The switch, normally open, closes when the pump goes into operation and remains closed as long as the pump is discharging water.

II. Priming Valve—This is an automatic valve which is mounted on the top of the centrifugal pump casing. It permits the passage of air through it during the priming operation, but closes when water at the operating pump pressure attempts to flow through it. It remains closed only so long as the pump is in operation.

III. Vacuum Breaker with Priming Switch—This unit is mounted so as to be higher than the priming valve. Air exhausted by the priming pump passes through the pump casing, then through the priming valve and vacuum breaker to the priming pump. The action of the vacuum breaker is: (1) to prevent water from entering the priming pump, (2) to actuate the priming switch when priming is completed, (3) to automatically drain and prepare for a new priming cycle once the pump is in operation. The priming switch is normally open. When the water enters the vacuum breaker chamber, the float rises and simultaneously closes the switch and opens an air valve. Air, entering through this valve, breaks the vacuum and permits the water to drain out of the chamber.

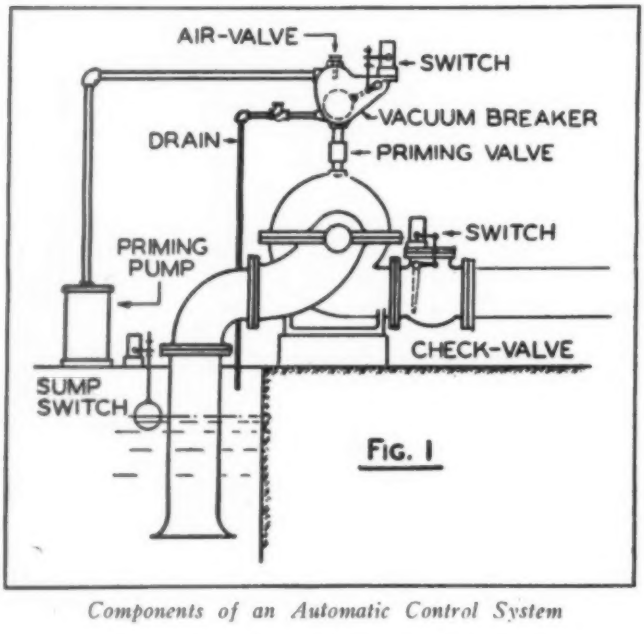


FIG. 1

Components of an Automatic Control System

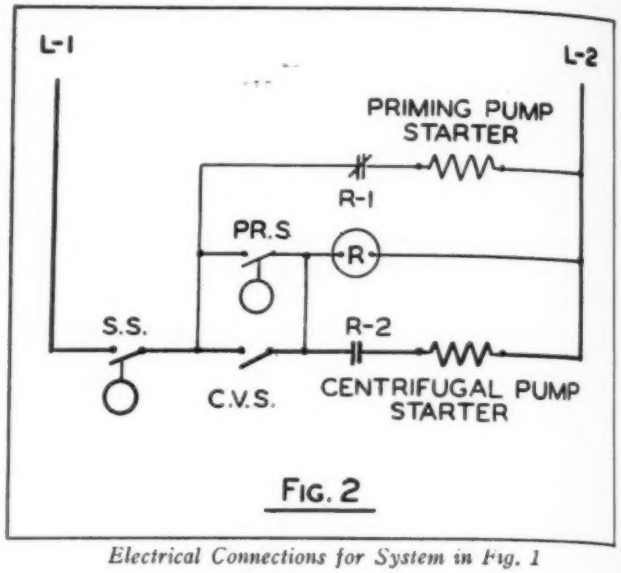


FIG. 2

Electrical Connections for System in Fig. 1

For safe and dependable control of pumps operating with a suction lift, a vacuum pump is used. Reduced pressure produced by the vacuum pump permits the water to rise from the sump into the pump, filling the pump casing and float chamber. As the float in the chamber rises, it operates the priming switch which is connected with the starting circuit of the centrifugal pump motor. Shutting down of the priming pump is also accomplished at the same instant.

In its simplest form these arrangements are shown diagrammatically in Figure 1. The check valve prevents the entrance of air during the priming period and arrests the back flow of water when the discharge line is filled and the pump stands idle. In the latter condition, the pump in starting must produce a pressure sufficiently great to open the main-line check valve against the full water column pressure. This fact makes priming difficult when there are air pockets in the suction line. The air from these pockets, when drawn into the pump, gathers around the impeller hub, causing the pump to lose suction and preventing it from building up sufficient pressure to start the flow of water through the check valve.

In order to remove this air, the pump must be stopped and allowed to remain idle sufficiently long for all the entrapped air to rise to the top of the pump casing. It can then be removed by the priming pump at the next priming attempt.

It is therefore evident that automatic control must provide for more than one start and for a delay between starts. Not only air pockets, but also air leaking through the stuffing boxes may destroy the prime. At the first start, water is forced into the water seal ring of the stuffing box. This stops or so greatly reduces the leakage that the pump will be properly primed after two or perhaps three priming attempts.

Should the seal water not stop the leakage, there may result a continuous starting and stopping of the priming pump and the centrifugal pump. Automatic control must therefore limit the number of starts to three or four. The justification for this feature was clearly illustrated by experience in early automatic installations. In one instance, one standard automatic starter for a squirrel cage motor made 450 starts from 1 p. m. Monday afternoon to 7 a. m. Tuesday morning, a total of 25 starts per hour for 18 hours. This starter was roasted.

The air leak may be so large that the priming pump cannot dispose of all the air leaking into the system and therefore cannot draw the water into the float-chamber. In that case, the priming pump will continue to run indefinitely. Thus in order to prevent damage to the priming pump or over-flowing of the sump, automatic control should limit the time required for priming.

Referring again to Figure 1, the priming valve is held open by the action of a spring and closed by water pressure when the pump begins to discharge water. As soon as this valve closes, the float-chamber begins to drain and its switch will open. It is

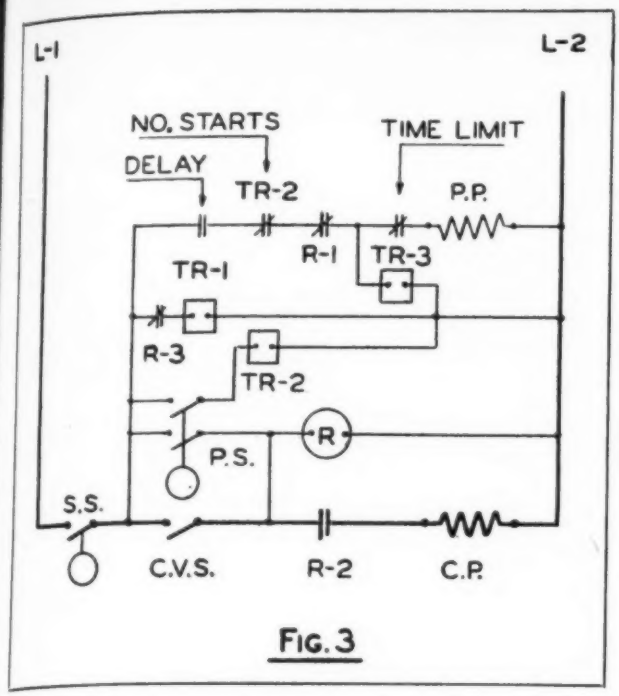


FIG. 3

The Time Relay Circuit for Preventing False Pump Starts

important that the float-chamber drain slowly so that sufficient time is permitted for the pump to build up speed and close the check valve switch before the priming switch opens. If this did not happen, the pump would immediately stop.

Electrical Circuits

Figure 2 shows the electrical connections for the above arrangement. When the water rises in the sump, closing the sump switch, current flows from Line 1, through the sump switch, SS, and the normally closed contact, R-1 of the relay R, thus energizing the priming pump starter. The priming pump begins operation. When priming is completed and the water rises into the priming chamber, the priming switch closes, energizing the relay R. This opens contact R-1, stopping the priming pump, and closes R-2, energizing the centrifugal pump starter. As the pump builds up speed and begins to discharge water, the check valve switch will shunt out the priming switch. The priming switch opens as the priming chamber drains. The importance of slow draining of the chamber can be readily understood here. The pump is now operating under protection on the check valve switch. Should the pump lose the water, the check valve switch will open, and the pump will stop. Relay R is no longer energized and R-2 drops out and R-1 closes again. If the sump switch is still closed, the priming cycle will be repeated.

Prevention of False Starts

To prevent too many false starts, a time relay is placed in the circuit, controlled by the vacuum breaker switch. The simplified wiring diagram, with other features, is shown in Figure 3. The timing action of this relay, TR-2 occurs only while the priming switch is closed. When a sufficient time for several priming attempts has elapsed, TR-2 opens.

The complete automatic action is exemplified by Figure 3. This action is as follows: When the water in the sump rises and closes the sump switch, SS, current flows from Line 1 through normally closed contact R-3 and time delay relay, TR-1, to Line 2. Then, TR-1 begins to time. After it has timed out, contact TR-1 closes and now permits current to flow through the normally closed contact TR-2 of time relay TR-2, then through the normally closed contact R-1 and through the normally closed contact TR-3 of time relay HR-3, to the priming pump starter which is now energized and starts the priming pump. When priming is completed and the priming chamber is filled, the priming switch PS closes and time relay TR-2 begins to time. At the same instant, relay R is energized, closing R-2 and opening R-3 and R-1, thus the centrifugal pump starter is energized and the pump starts; the priming pump stops and time relay TR-1 is reset.

Time relay TR-2 is cumulative, i.e., TR-2 opens only when the total time required for several normal starts is exceeded. Time limit relay, TR-3, is set for about 15 to 30 minutes to limit the time of operation of the priming pump during any one prime. Time delay relay, TR-1, has been reset by the opening of R-3 so that it will be able to delay a second priming attempt if the first was unsuccessful. Since large pumps are idle for as long as 30 seconds, TR-1 is set to trip in about one minute. If the pump is still not in operation after several priming attempts, time relay TR-2 locks out so that the system now completely ceases operation, but an alarm signal sounds either in the foreman's office or at any desired location. The system will not operate again until the trouble has been remedied and time relay, TR-2, reset by hand. Note, however, that all relays must automatically reset when the sump switch opens.

It is not the intention of this article to give a detailed description of the mechanical and electrical devices. These may vary considerably but they should provide the sequence of operation and protection outlined. Additional features such as pressure and vacuum regulator switches, water level indicators, thermostats on the pump main and thrust bearings, etc., may be added for greater safety. The most recent innovation is the use of electrodes in the sump in place of float switches.

PRESSURE IN POUNDS PER SQUARE INCH FOR DIFFERENT HEADS OF WATER

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81.84
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

SPECIFIC SPEED CURVES*

Single Stage Centrifugal and Mixed Flow Pumps

IN 1932 a group of centrifugal pump manufacturers, members of the Hydraulic Institute, plotted curves representing the upper limits of specific speeds, in respect to head and dynamic suction lift, to which, according to their experience, centrifugal pumps may be applied with reasonable assurance of freedom from cavitation. These curves have proved valuable to users of pumps, as well as to the manufacturers. More recent experience and additional information have resulted in revisions:

The following examples illustrate the use of the new curves, here reproduced by courtesy of the Hydraulic Institute.*

Example I—Single-Suction Pump with Shaft Through Eye of Impeller

Given a total dynamic head of 100 feet and a dynamic suction lift of 15 feet, what is the safe upper limit of specific speed to avoid danger of cavitation?

Referring to the first chart (Fig. 1), the intersection of the diagonal for 15 feet suction lift with the horizontal line at total pump head of 100 feet, falls on the vertical line corresponding to 2250 specific speed on the scale at the top of the sheet. The specific speed should not exceed this value.

Example II—Double-Suction Pump

Given a total dynamic head of 100 feet and a dynamic suction lift of 15 feet, what is the safe upper limit of specific speed?

Referring to the first chart (Fig. 1), the intersection of the

*Note:—These revised curves, which have been approved by all the leading pump manufacturers, are available in larger dimensions from the Hydraulic Institute, 90 West St., New York City, at a nominal charge.—Ed.

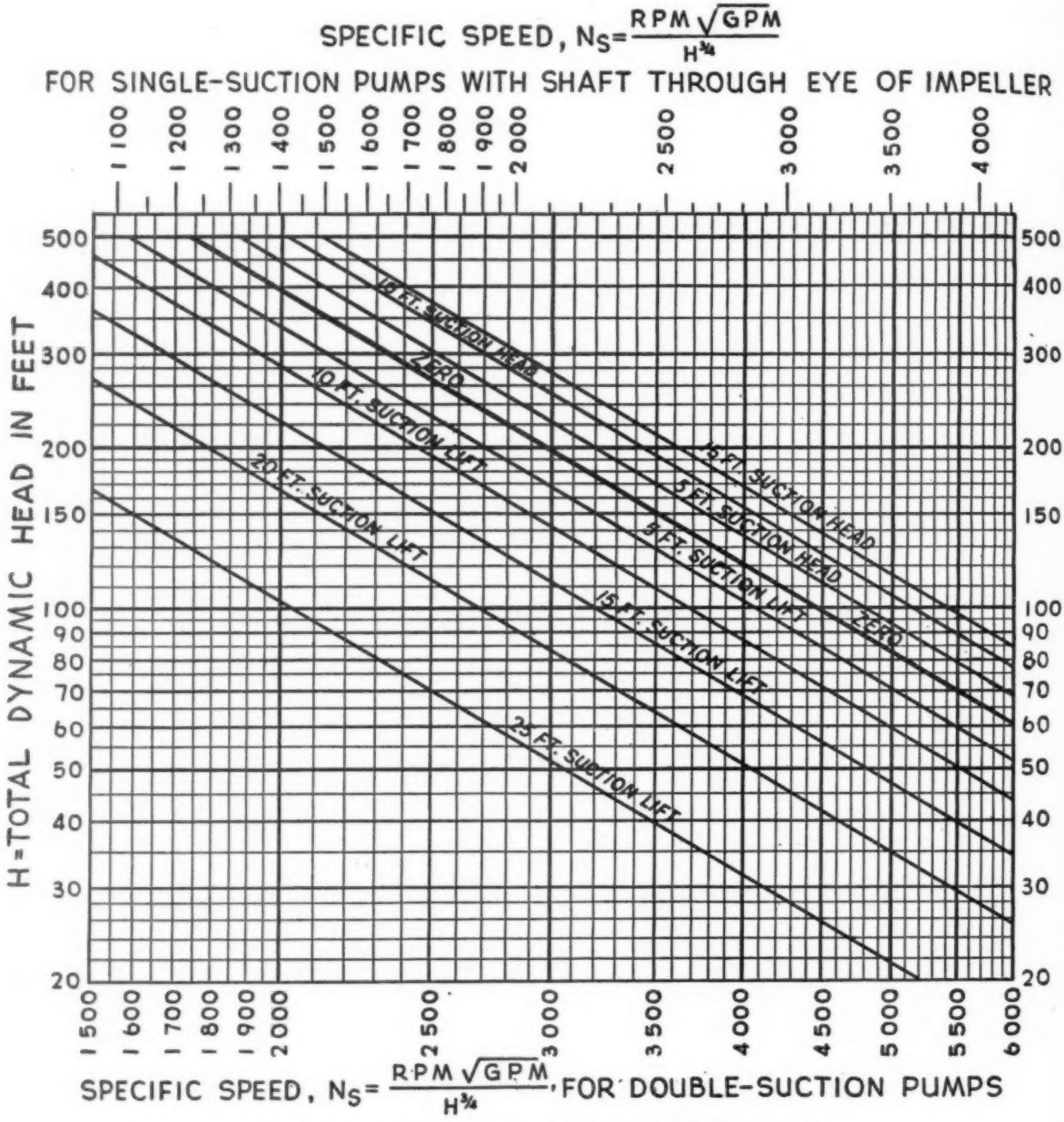


Fig. 1—Upper Limits of Specific Speeds for Single Stage Pumps.
(Pumping Clear Water at Sea Level at 85° F. For convenience, Values of H¾ for Various Heads Appear in Fig. 3.)

diagonal for 15 feet suction lift with the horizontal line for 100 feet total pump head, falls on the vertical line corresponding to 3200 specific speed on the scale at the bottom of the sheet. This is the value of $\frac{\text{rpm} \times \sqrt{\text{gpm}}}{\text{H } ¾}$ in which the value of gpm is the

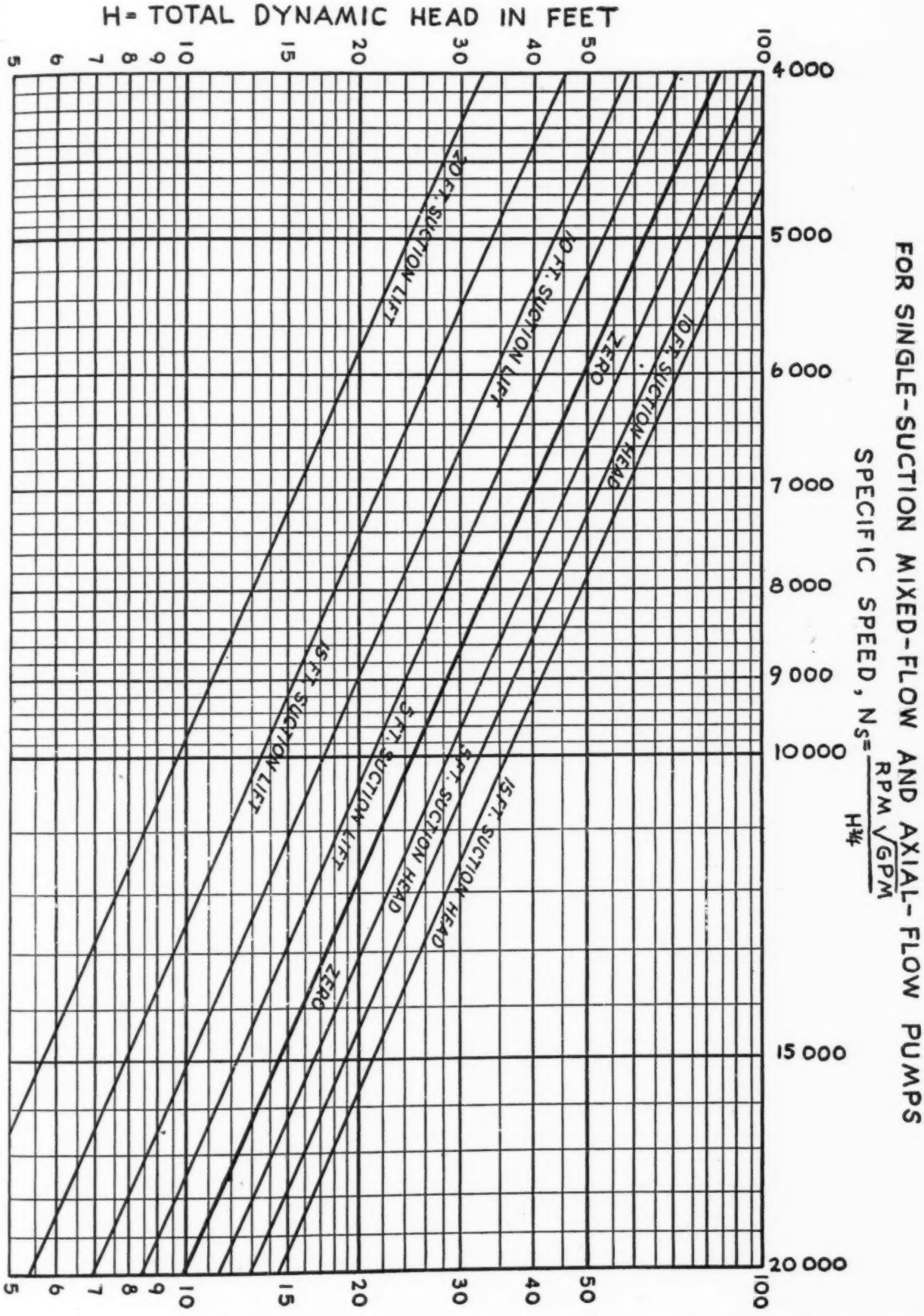


Fig. 2.—Upper Limits of Specific Speeds for Mixed-Flow and Axial-Flow Pumps. (Pumping Clear Water at Sea Level at 85° F.)

total gallons per minute capacity of the pumping unit including both suctions, and is the highest value which should be used for this head and suction lift.

Example III—Single-Suction Mixed-Flow or Axial-Flow Pump

Given a total dynamic head of 35 feet and positive dynamic suction head of 10 feet, corresponding to a submerged impeller, what is the safe upper limit of specific speed?

Referring to the second chart (Fig. 2), the intersection of the horizontal line for 35 feet total pump head and the diagonal for 10 feet suction head, falls on the vertical line corresponding to 9400 specific speed on the scale at the bottom of the sheet. The specific speed should not exceed this value.

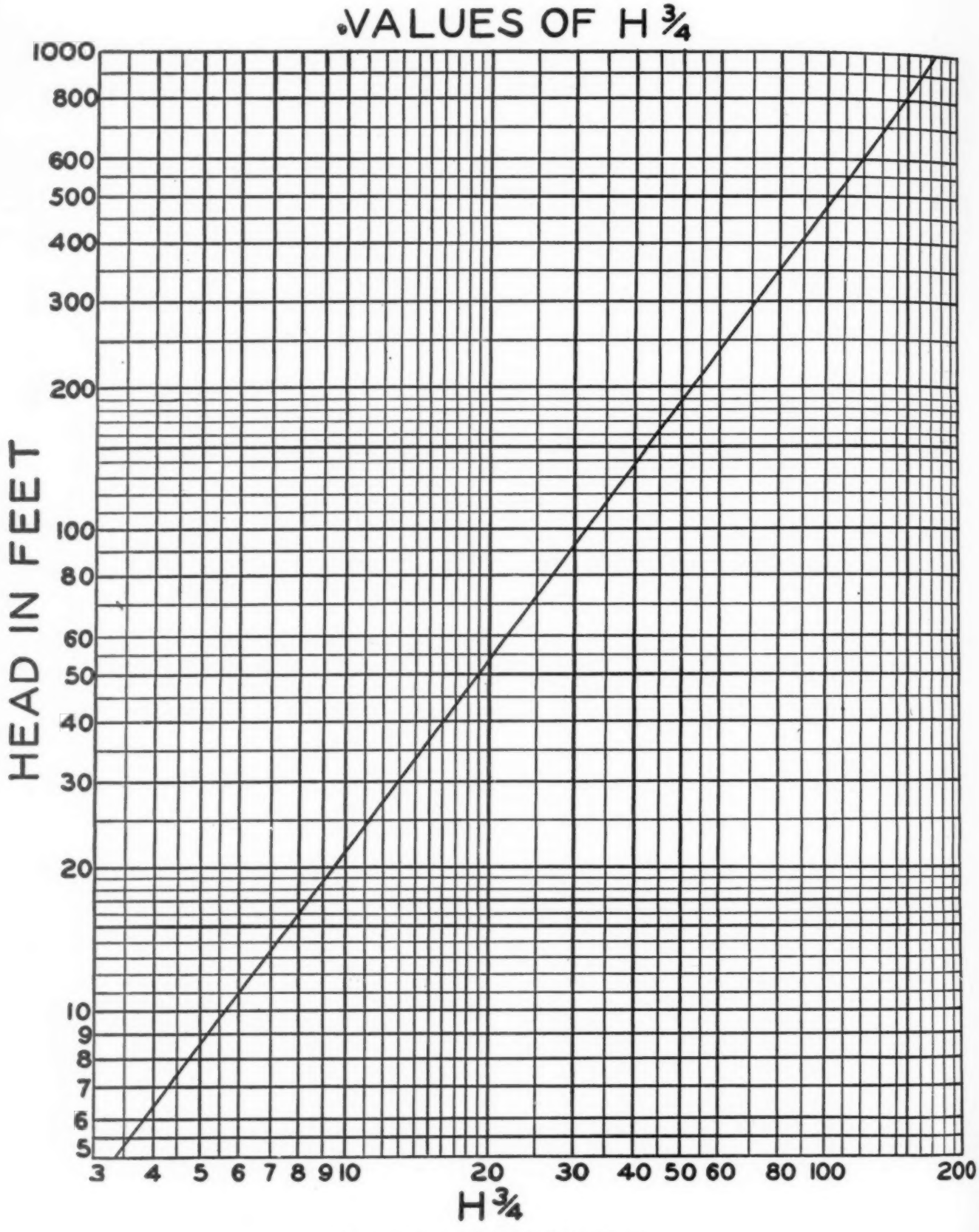


Fig. 3.—Values of H¾ for Various Heads.

SUBMERGENCE AND SPACING OF SUCTION BELLS

By C. A. RICHARDSON
Centrifugal Pump Engineer
Allis-Chalmers Mfg. Co., Milwaukee, Wis.

WHENEVER large centrifugal pumps are to be installed, the question of permissible submergence of suction bell and unit spacing always arises. This is as it should be, for the satisfactory operation of centrifugal pumps is largely dependent upon the suction conditions, and it is particularly important that careful consideration be given the suction conditions at the time the location and layout of suction bells are established.

On large waterworks or sewerage installations it is of prime importance that proper suction conditions are obtained.

When laying out the location of suction bells careful consideration should be given to the following:

(1) Distance of suction from bottom of pit.

(2) Distance between suction bell and any obstruction.

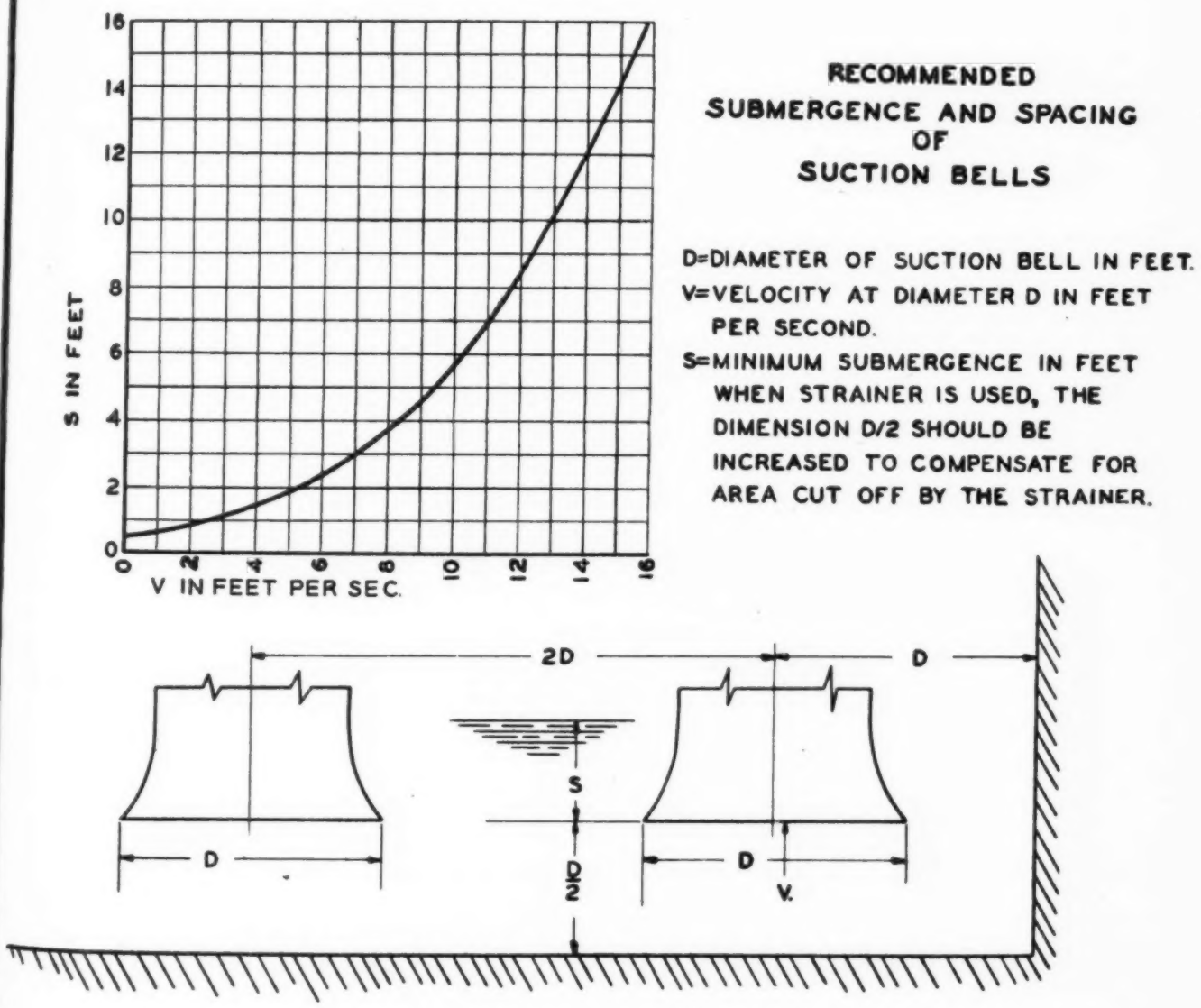
(3) Distance between units.

(4) Minimum submergence of suction bell for maximum flow.

The accompanying diagram and curve shows the minimum relation of these factors recommended by the writer's company as representing good practice.

It is necessary that the flow in the region of the suction bell be free from vortices. Any change in direction of flow, will tend to form vortices, and it is important that ample space between any obstruction, such as columns, other suction bells, walls, etc., be allowed to permit dissipation of the vortex before reaching the suction bell entrance.

The amount of submergence required to prevent formation of vortices at suction bell entrances is largely dependent upon the entrance velocity. The accompanying curve gives the minimum suggested submergence. This curve is based on smooth non-turbulent flow into suction bell.



RECOMMENDED SUBMERGENCE AND SPACING OF SUCTION BELLS
(Developed by Allis-Chalmers Mfg. Co.)

PUMP POUNDING CORRECTED BY SIMPLE "AIR SNIFFER"

By D. R. TAYLOR, Plant Superintendent
Roanoke Water Department, Roanoke, Virginia

THE annoying dull pounding on the accentuation of pulsations, as the lesser of the two evils in the operation of piston pumps, is usually the result of a deficiency of air in the cushion chamber on the discharge end of the pump.

To eliminate this deficiency it is not necessary to go to the expense of installing an air compressor. The trouble can be eliminated much more inexpensively by the installation of a simple anti-"pulsationitis" gadget which we have dubbed our air "sniffer." The accompanying sketch pictures the installation which should be made from readily procurable parts, as follows:

There is probably a plug or a drain pipe in the bottom of your pump casing. Install a ½ in. line (A) from this point to a point slightly above the top of the air chamber with a renewable seat globe valve (B) in this line. The length of a nipple below the top of it is a good location.

At the top of this line, install a tee (C) with the side outlet looking down, and after drilling and tapping the top of the air chamber, connect one end of this tee to the top of the chamber with another globe valve (E) and a check valve (D) between the tee and the chamber. This check should open for a flow toward the chamber.

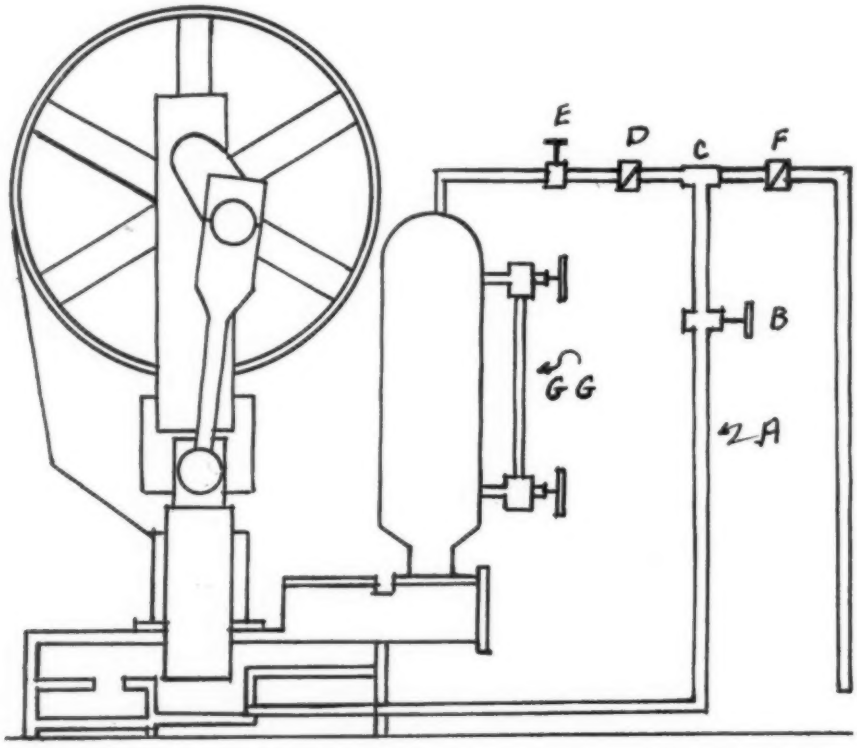
At the other end of the tee, install a 6 in. nipple and another check valve (F), also set for a flow toward the chamber. Complete the line with a short nipple, a 90 degree elbow, and a length of ½ in. pipe dropping almost to the floor. This is done so that any drippings from this line will be near the floor and, therefore, will not spatter your pump room and equipment.

Then purchase from your local mill supply dealer a gauge glass (GG) and install it on the side of the air chamber for an easy and quick determination at any time of the quantity of air in the chamber.

When the air needs replenishing, open valves (E) and (B) and the pump will do the trick automatically. On the up or suction stroke of the pump plunger, check valve (D) will remain closed, check valve (F) will open, of course, and air will be drawn into line (A). On the down stroke, check valve (F) will close and check valve (D) will open. The charge of trapped air will be forced into the air chamber.

Let me warn you, however, that this little gadget is much more vivacious than you might at first suspect. Only a few minutes are required to fill the chamber and, if the "sniffer" is allowed to operate too long at one "sitting," you may experience the annoyance of having too much air, possibly to the extent of aerating your transmission or distribution main. With a little experience, you will soon be able to determine the necessary frequency and length of time to operate the "sniffer" to satisfy your particular conditions, and then you can cross off another item from your headache list.

We have successfully operated one of these gadgets on a five million gallon per day steam pump and one on a nine hundred thousand gallon per day motor driven triplex pump for a number of years with perfect satisfaction.



Sketch showing the method of installation of the "sniffer" on a triplex plunger pump.

PUMP TROUBLE CHECK SHEET

(Courtesy, Goulds Pumps, Inc.)

WHEN investigating trouble with Goulds Pumps, always remember that every pump has been tested at the factory and is mechanically correct when shipped. Discounting the possibility of damage during shipment, most of the trouble in the field is due to faulty installation. Check the following points:

Centrifugal Pumps

Investigation shows that the majority of troubles with CENTRIFUGAL PUMPS result from faulty conditions on the suction side. Except for mechanical trouble, nine times out of ten, this is where to look for the cause.

1. No water delivered

(a) Priming—Casing and Suction Pipe not completely filled with liquid
x (b) Speed too low
(c) Discharge head too high—check vertical head (particularly friction loss)
(d) Suction Lift too high (suction pipe may be too small or long causing excessive friction loss). Handling cold water, total lift including friction loss in suction pipe should not exceed 15 feet, or in any case be more than 2/3 total head. Check with gauge.
(e) Impeller or suction pipe or opening completely plugged up
(f) Wrong direction of rotation
(g) Air pocket in suction line
(h) Stuffing Box Packing worn—or water seal plugged—allowing leakage of air into pump casing
(i) Air leak in suction line
(j) Not enough suction head for hot water or volatile liquids. Check carefully as this is a frequent cause of trouble on such service

2. Not enough water delivered

(a) Priming—Casing and Suction Pipe not completely filled with liquid
x (b) Speed too low
(c) Discharge head higher than anticipated—check, particularly friction loss
(d) Suction Lift too high (suction pipe may be too small or long causing excessive friction loss). Handling cold water, total lift including friction loss in suction pipe should not exceed 15 feet nor in any case be more than 2/3 total head. Check with gauge
(e) Impeller or suction pipe or opening partially plugged up
(f) Wrong direction of rotation
(g) Air pocket in suction line
(h) Stuffing Box Packing worn—or water seal plugged—allowing leakage of air into pump casing
(i) Air leak in suction line
(j) Not enough suction head for hot water or volatile liquids. Check carefully as this is a frequent cause of trouble on such service
(k) Foot Valve too small
(l) Foot Valve not immersed deep enough
(m) Mechanical defects:
Wearing rings worn
Impeller damaged
Casing packing defective

3. Not enough pressure

x (a) Speed too low
(b) Air in water
(c) Measure Impeller diameter
(d) Mechanical defects:
Wearing rings worn
Impeller damaged
Casing packing defective
(e) Wrong direction of rotation
(f) Be sure pressure gauge is in correct place. Not on top of casing

4. Pump works for a while and then quits

(a) Leaky suction line
(b) Stuffing Box Packing worn—or water seal plugged—allowing leakage of air into pump casing
(c) Air pocket in suction line
(d) Not enough suction head for hot water or volatile liquids. Check carefully as this is a frequent cause of trouble on such service
(e) Air or gases in liquid
(f) Suction Lift too high (suction pipe may be too small or long causing excessive friction loss). Handling cold water, total lift including friction loss in suction pipe should not exceed 15 ft. nor in any case be more than 2/3 total head. Check with gauge

5. Pump takes too much power

(a) Speed too high
(b) Head lower than rating: pumps too much water
(c) Liquid heavier than water. Check viscosity and specific gravity
(d) Mechanical defects:
Shaft bent
Rotating Element binds
Stuffing Boxes too tight
Pump and Driving Unit misaligned
(e) Wrong direction of rotation

6. Pump leaks excessively at stuffing box

(a) Packing is worn or not properly lubricated
(b) Packing is incorrectly inserted or not properly run in
(c) Packing is not right kind for liquid handled
(d) Shaft scored

7. Pump is noisy

(a) Hydraulic noise-cavitation, suction lift too high. Check with gauge
(b) Mechanical defects:
Shaft bent
Rotating parts bind, are loose or broken
Bearings worn out
Pump and driving unit misaligned

x When connected to electric motors, check up whether motor is across the line, wiring correct, and receives full voltage. When connected to steam turbines, make sure that turbine receives full steam pressure.

Vertical Centrifugal Sump Pumps

In general, the same remarks as given for "Centrifugal Pumps" apply to these units. By the very nature of the service on which they are commonly used, lack of capacity or pressure can be caused by clogging due to the solid matter in suspension in the liquid handled.

This, in addition to the other general remarks should always be checked and if clogging occurs, adequate screening of pump suction should be provided.

Lack of capacity or pressure may be because total head was incorrectly figured. Total head of a sump pump is vertical elevation from water level in sump (not pit cover) plus friction loss in piping from pump nozzle to point of discharge.

Triplex Pumps

1. No water delivered

(a) Priming—(Fill Valve Boxes and Pump Cylinders with water)
(b) Suction Line completely plugged up
(c) Suction Lift too high (over 22 ft.) Check with gauges
(d) Not enough positive suction head for hot water volatile or thick liquids

2. Not enough water delivered

(a) Priming—Fill Valve Boxes and Pump Cylinders with water
x (b) Speed too low
(c) Foreign matter under valves
(d) Suction line partially plugged up
(e) Suction Lift too high (over 22 ft.) Check with gauges
(f) Not enough suction head for hot water, volatile or thick liquids
(g) Mechanical defects:
Valves worn or warped and do not seat properly
Plunger Packing worn
Plungers worn

3. Not enough pressure

(a) Air in water
(b) Foreign matter under valves
(c) Mechanical defects:
Valves worn or warped and do not seat properly
Plunger Packing worn
Plungers worn

4. Pump pounds

(a) Air in water
(b) Suction Lift too high (over 22 ft.) Check with gauges
(c) Surges in suction line (especially on booster pumps)
(d) Not sufficient suction head for hot water, volatile or thick liquids
(e) Excessive speed
(f) Speed too high for thick, viscous or hot liquids, so that pump barrel cannot fill
(g) Pressure greater than catalog rating of pump. Excessive strain on moving parts and frame
(h) Mechanical defects:
Loose main bearings
Loose crossheads
Loose crosshead pins
Loose crank pins

5. Pump takes too much power

(a) Speed too high
(b) Higher pressure than catalog rating of pump
(c) Liquid heavier than originally specified. Check viscosity and specific gravity
(d) Plungers packed too tight
(e) Mechanical defects:
Poor fitting of moving parts
Bearings too tight
Gears not properly assembled
x See note under Centrifugal Pumps

Rotary Pumps

1. No water delivered

(a) Priming—See that Casing and Suction Pipe are filled with liquid
(b) Suction Line completely clogged
(c) Suction Lift too high (Suction pipe may be too small or long causing excessive friction loss.) Check with gauges
(d) Wrong direction of rotation
(e) Not enough positive suction head for hot water, volatile or thick liquids

2. Not enough water delivered

(a) Priming
x (b) Speed too low
(c) Suction Line partially clogged
(d) Suction Lift too high (Suction pipe may be too small or long, causing excessive friction loss.) Check with gauges
(e) Not enough positive suction head for hot water, volatile or thick liquids
(f) Liquid too thick or viscous. Check viscosity

3. Not enough pressure

(a) Air in water or liquid
(b) Mechanical defects:
Cams, Gears or other working parts worn—too much clearance
Stuffing Box Packing worn

4. Pump makes too much noise

(It must be borne in mind that some noise is always natural in a rotary pump)
(a) Air in water or liquid handled
(b) Speed too high—especially when handling thick or volatile liquids
(c) Too much suction lift—pump not filling with liquid
(d) Mechanical defects:
Cams, Gears, or other working parts worn, loose or broken

5. Pump takes too much power

(a) Speed too high
(b) Discharge pressure higher than originally specified
(c) Liquid heavier than originally specified. Check specific gravity and viscosity
(d) Stuffing Box Packing too tight
(e) Mechanical defects.
Poor fit of working parts—binding at some point
Bearings too tight
Misalignment between pump and driver
x See note under Centrifugal Pumps

Centrifugal Pumps

Total suction lift must never exceed suction lift limits of pump. The remarks in the trouble check lists apply to Centrifugal Pumps in general. It must be borne in mind that when dealing with very small Centrifugal Units, 1" size and less, suction lift is further limited, and in some cases a positive head is absolutely necessary to secure proper operation. The recommendations in our catalog for these 1" and smaller pumps should be followed.

Use pipe of ample size—at least the same diameter as suction of pump. Suction pipe should have sufficient submergence to prevent air from being indrawn. Suction pipe should be air tight and slope gradually up towards pump to prevent air pockets. If suction pipe is larger diameter than suction opening of pump, an eccentric reducer should be used to prevent high spot in line and formation of air pocket.

Check Valve in discharge line close to pump to prevent draining back thru pump.

Gate Valve next to Check Valve, on far side of pump, to close off line for pump or check valve repairs and to control capacity of pump.

An air tight suction pipe and properly sealed stuffing box especially important with Centrifugal Pumps which are not positive in action.

Stuffing Box is sealed usually by water under pressure from casing volute. This seal pipe and lantern ring in stuffing box should be clean and offer free flow to liquid—otherwise air drawn into pump and satisfactory operation destroyed.

Reciprocating and Rotary Pumps

For safety a relief valve set to open slightly above maximum pump pressure should be installed in discharge line near pump.

EVALUATION OF PUMP BIDS BY A SIMPLE METHOD AND DETERMINATION OF POWER COSTS

The estimated cost of electrical energy for pumping liquids over any assumed period of time, which is to be added to the bid price for pumping equipment for determination of its evaluated cost, may be obtained through the use of the formula

$$C = \frac{3.14\ Qhc}{E}$$

Where C = Estimated power cost in dollars over the assumed evaluation period.
Q = Estimated number of *millions* of gallons to be pumped during the same period.
h = Head in feet, on which guaranteed efficiency is based.
c = Cost, in dollars, per KWH of electrical energy.
E = Guaranteed overall pump and motor (input-output) efficiency at head "h," expressed as decimal fraction and not as a percentage.

The constant "3.14" is suitable for slide rule calculations and is sufficiently accurate for most cases, as the assumptions made are too broad for accurate estimates. Should it be necessary to determine the cost to the dollar (in case of very close bids and the selection must be made on a price basis), the figure 3.13975 should be used.

Example: Assume
Q = 2,000 million gallons
h = 100 feet
c = $0.01 per KWH
E = 0.7 (70 per cent)

$$C = \frac{3.14 \times 2{,}000 \times 100 \times 0.01}{0.7}$$

$$= \$8{,}970.$$

This simplified formula for evaluating pump bids was developed by C. I. Dodd of Black & Veatch, Engrs., Kansas City, Mo.

SELECTING DEEP WELL CENTRIFUGAL PUMPS

By AXEL O. FABRIN
Pump Designer, Memphis, Tenn.

PART I

The Deep Well Pump and Factors Affecting Pump Systems

ENGINEERS, scientists, in fact all men who follow vocations that are technical in character, find pleasure in contemplating great historical changes or cycles of social development.

Social developments, like history, are matters of record, and in a large measure are dependent on historical changes, but aside from the companionship we find that the inventive genius of man is a fundamental requisite. It is the persistent urge to improve methods and machines that makes possible social developments which are enjoyed in our every-day life.

History of military exploits and political machinations is something we can read about in our leisure time, or we can deny ourselves this pleasure, but we cannot escape the form and degree of civilization brought about by social developments.

Water and pumps can, by reason of their importance, justify their associations with history and social development. The pump, unlike water, has not existed since the beginning of time, and it is not intended to infer that without pumps life would cease, but the pump does rightfully come into its claim of importance because it has made possible a great extension of man's activity and consequent economic progress in the production of manufactured articles, and by making fertile and agriculturally useful a large portion of the arid lands of the earth.

The Deep Well Centrifugal Pump

The type of pump known as the deep well centrifugal needs no press agent, since it is not the result of an artificially created desire, but rather is a machine designed to convey or furnish by its unique performance the most vital substance of life. Where water is procurable in abundance and can be controlled, there the density of human habitation is greatest.

Control of water delivery is best obtained through the use of pumps and, where the source of supply is wells, the deep well centrifugal pump is almost indispensable.

The deep well centrifugal pump, as its name suggests, is designed to enter and extend down into wells where it reaches the water deep in the earth, and lifts it to the surface. (See Fig. 1.) The hydraulic member of the pumping unit is the pump body which is submerged in the well. It is suspended from the earth's surface by a pipe which conducts the water upward and this pipe includes in its extensive length a driving shaft. This driving shaft attached to a motor at the surface transmits power in rotative form which pins the impellers located within the submerged pump body. One spinning impeller will elevate water a certain height. Two impellers will elevate water twice as high. By adding impellers any practical height or lift can be accomplished.

Pumps having two or more impellers are called multi-stage. In multi-stage pumps the space between successive impellers can be made equal to the distance each one will elevate the water. Thus, if one stage will boost water twenty (20) feet, the lowest impeller will elevate water up to the second stage, which will pick up the water and boost it twenty (20) feet higher. Five impellers spaced twenty (20) feet apart would then discharge water at the ground surface from a water level one hundred (100) feet down in the well. It has been found, however, that locating one stage immediately above another produces the same results as when they are spread apart.

Manufacturing economy and engineering reason dictate the practice of nesting impellers in an assembly of close coupled pump bodies. This assembly is the deep well centrifugal pump and constitutes one part of a complete pumping unit. (See Fig. 2.)

History

Before discussing the deep well pump, a review of the history of water pumps may prove an incentive to regard engineering on the subject more intensely.

Moving water by pumps traces its first performance to about the year 200 B.C. Previous to that period there is no mention made of pumps, and there has not been discovered any portion of history that makes reference to such a machine prior to that time.

Even the Chinese, who claim priority in many accomplishments, do not mention the use of pumps in early times, even though we consider that irrigation was common with them. Rude nations did not possess the machine, simple as it is, but resorted to laborious manual methods of raising water. From crude wells or cisterns, water was drawn by pitchers attached to cords raised or lowered by hand.

The ancient Egyptian water wheel, so common all over Asia, was turned by a stream without any appreciable fall, and, at its outer circumference, was equipped with buckets which raised water and discharged it into a trough. This form of wheel appeared in Spain and was given the name of "Noria." Danish missionaries in Siam discovered a modification of the "Noria" which consisted of a wheel turned by an ass and carrying around it not buckets but a band of hay which collected water and delivered it into a wooden trough.

The pump was spoken of as a curiosity by the inventors and engineers of the Alexandrian School, where most of the sciences were born. Hero, one of these inventors, did prepare a treatise on the

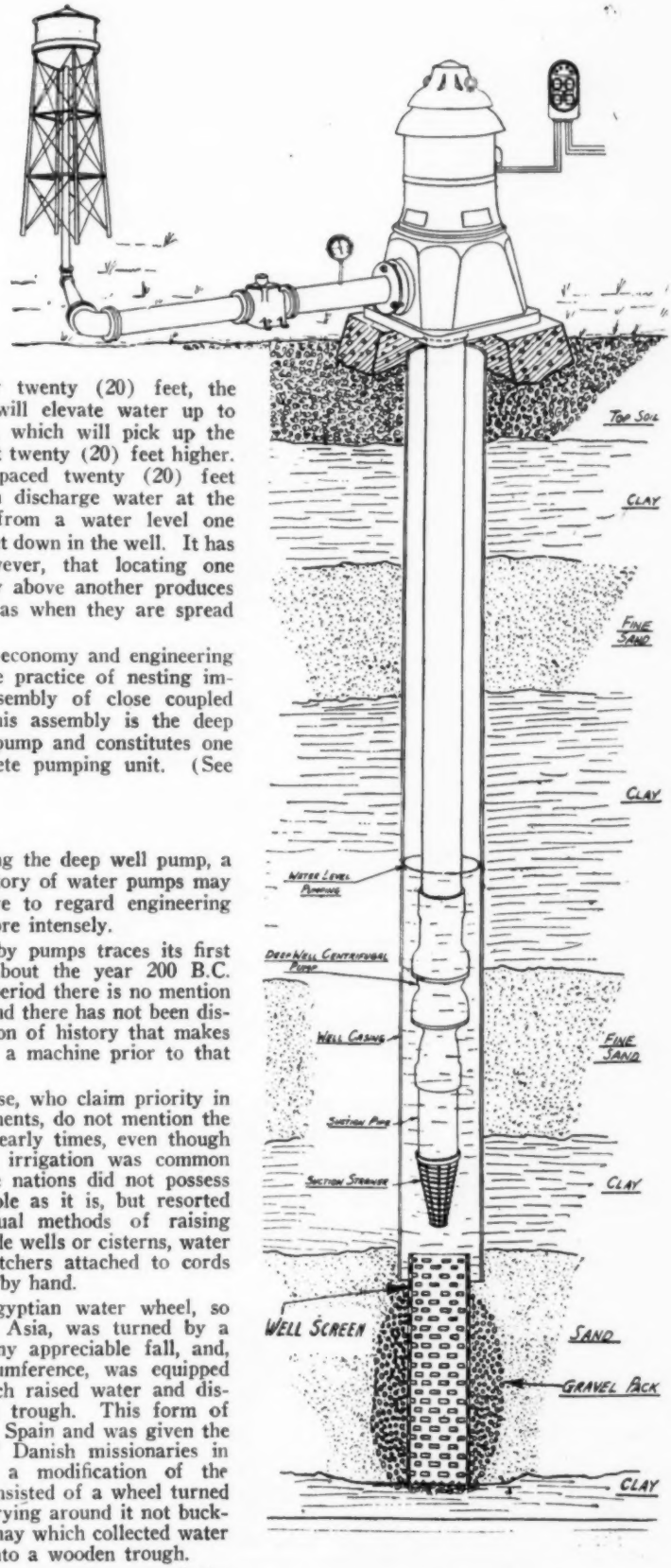


Fig. 1—Modern Well and Motor Driven Deep Well Centrifugal Pump

expansion of steam, the slide valve, the check valve, and nearly a hundred other inventions which today would be classified under the head of "mechanical engineering." Strangely enough, the pump stands nearly last on the list of inventions.

It is interesting to note that in the annual report of the U. S. Geological Survey for the year 1900 the only mention of pumps is that relating to windmills. No other means of irrigation pumping is referred to. After that year keen interest was directed to the centrifugal pump because it handled much greater water volumes than the windmill pump.

The development of the deep well centrifugal, capable of pumping large quantities of water from the underground water reservoirs, provided the farmers of the plains with a solution for their water problems and, as a consequence, proved a great boon to the western farmer.

It has been the writer's business as a designing engineer to investigate a great many pumping units and, in a period of thirty years, he has had to acquaint himself with performance both good and bad, as realized in all the vicissitudes and all the stages of deep well pump development dating back to a period when the machine was first accepted as practical.

Early in the period when the machine was in a relatively crude state, nothing was found more helpful in the advance towards perfection than the experiences of field men who briefly but forcefully presented them in a spirit of constructive criticism. In the light of present-day development quite a few of these criticisms have proven correct. We must not forget, however, that many promises of performance were made by the seller and they were made in a sincere desire to serve the customer, and through it all there was the hope that the designing engineer, by some method yet unknown, could provide a machine that would with fidelity fulfill every promise.

The Modern Pump

Modern design has made possible the realization of some exaggerated claims made by early exponents of the deep-well pump. Through lessons learned in the hard school of experience, checked by tests in the laboratory and verified in the field, has come a method of pump design which almost justifies being categoried as a science. There is still much knowledge which at present is in the process of evolution, and like electricity we find that the phenomena of the centrifugal pump defies explanation, but does not defy control. Through experience it has been found possible to arrive at a balance between efficiency of operation and stability of performance.

For the purpose of a brief discussion, the well designed to deliver a specific quantity of water by deep well pumping can be divided into two related parts known as casing and screen. The casing, sometimes called the pump pit, extends from the surface down to some level which practice has proven best to exclude surface water or water from intervening strata yielding an undesirable quality of water. Below this casing is the screen located in the water-bearing formation.

The diameter, length, type and location of the screen depends on the water-bearing formation encountered. Geology is the determining factor in screen selection, and the well contractor best fitted to construct a well must know something of this science. Through experience, the best possible construction has proved to be that of a shutter-type screen arranged for gravel packing around its exterior to control the fine sand when maximum flow is secured from a water-bearing strata. This "gravel packed" well construction was originated by the late M. E. Layne and is now in almost universal use throughout this and other countries.

The production of water from wells of this type was much greater than that produced in the straight well, and this advance in the art of well construction naturally affected pump design.

In discussing the conditions which prevailed prior to these well improvements, we shall do well to consider in some detail the fundamental reasons for the proportions of the well and the well casing.

The well casing diameter can vary between wide limits, and the small diameter is the one which can be considered fixed. It can be no smaller than that permitting the development of the strata below, where the well screen is set. The limit for large diameters is infinite within the realm of practical economy.

Modern well construction made possible the use of the deep well centrifugal pump, commonly called the turbine pump. This machine overcame the shortcomings of the conventional volute type centrifugal, which, up to the beginning of this century, was installed vertically in pits dug by hand and curbed with wood, brick or concrete.

The pump pits for volute pumps extended to a depth where the first water-bearing

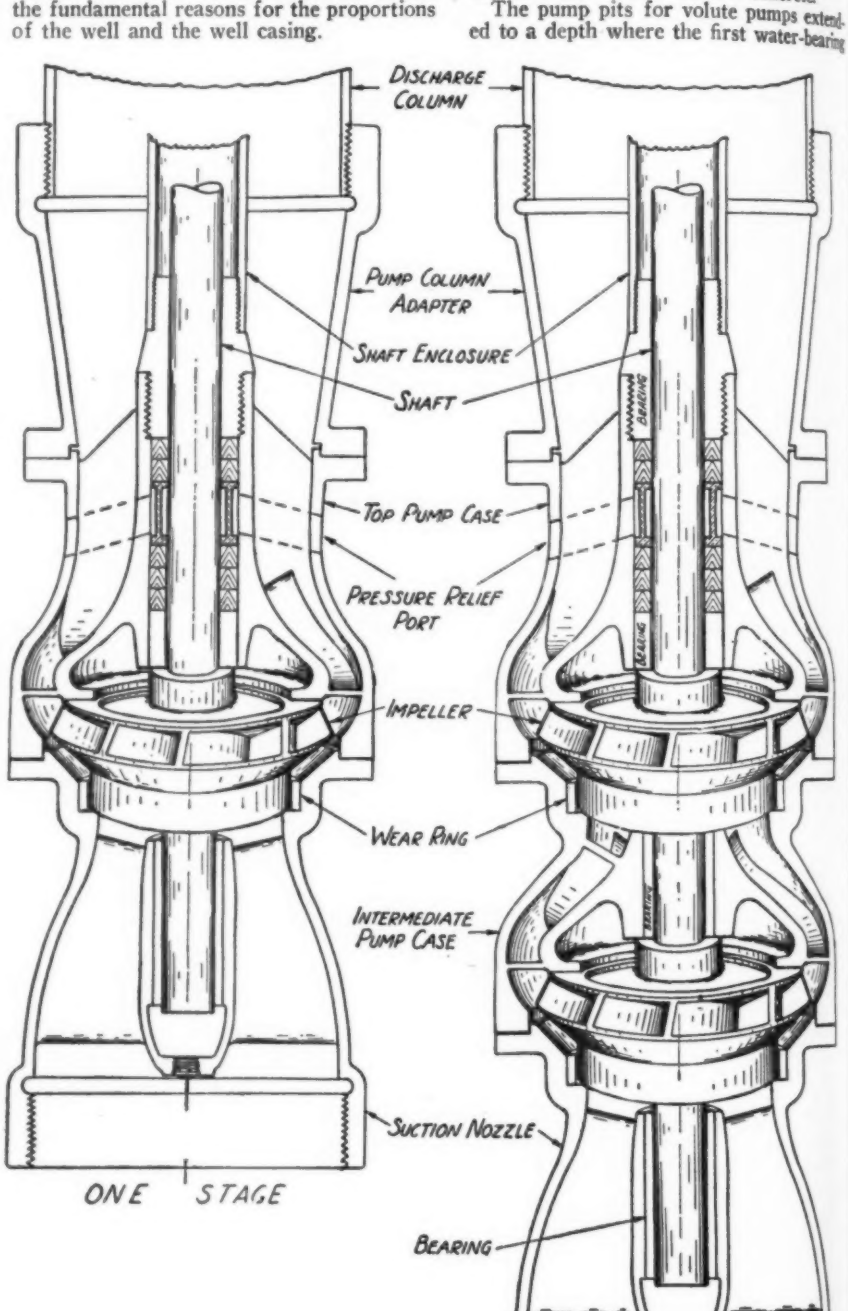


Fig. 2—Section Through Modern Deep Well Centrifugal Pumps

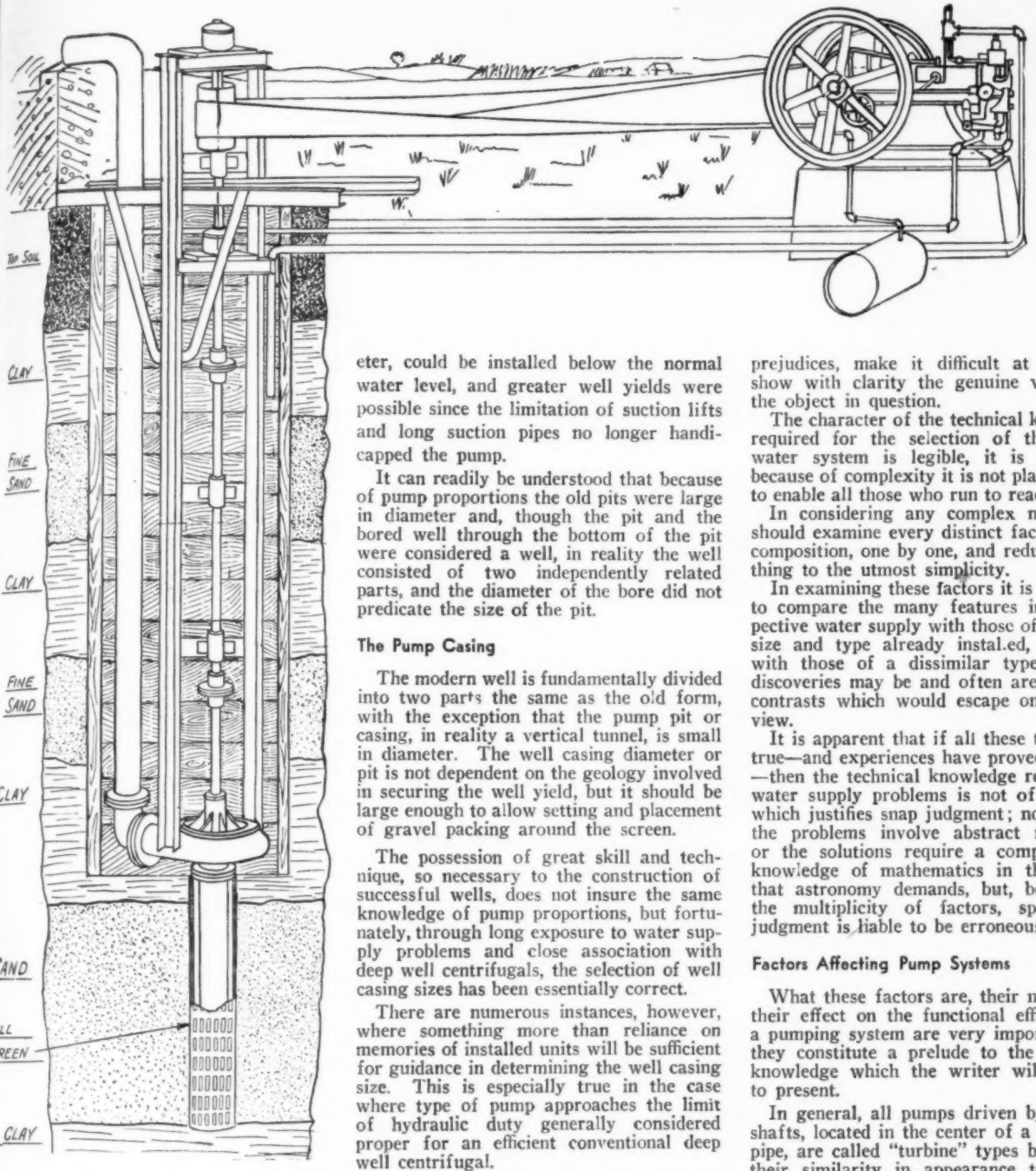


Fig. 3—Vertical Volute Pump Driven by Engine Through Belt (Installation in Open Well Pit)

formation was encountered, and then bored wells were extended through the bottom of this pit to other water-bearing strata. The volute centrifugal installed close to the bottom of this pit was fitted with long suction pipes entering the bored well and was driven by open line shaft supported either from the sides of the pit or a frame extending from the pump up to the surface. Usually these pumps were driven by means of a belt and pulley. (See Fig. 3.)

Many of the dangers of such a primitive set-up accompanied by inefficient operation, were obviated by the small diameter multi-stage deep well centrifugal pump which could be lowered into a pit of relatively small diameter. The deep well centrifugal pump, because of its relatively small diameter, could be installed below the normal water level, and greater well yields were possible since the limitation of suction lifts and long suction pipes no longer handicapped the pump.

It can readily be understood that because of pump proportions the old pits were large in diameter and, though the pit and the bored well through the bottom of the pit were considered a well, in reality the well consisted of two independently related parts, and the diameter of the bore did not predicate the size of the pit.

The Pump Casing

The modern well is fundamentally divided into two parts the same as the old form, with the exception that the pump pit or casing, in reality a vertical tunnel, is small in diameter. The well casing diameter or pit is not dependent on the geology involved in securing the well yield, but it should be large enough to allow setting and placement of gravel packing around the screen.

The possession of great skill and technique, so necessary to the construction of successful wells, does not insure the same knowledge of pump proportions, but fortunately, through long exposure to water supply problems and close association with deep well centrifugals, the selection of well casing sizes has been essentially correct.

There are numerous instances, however, where something more than reliance on memories of installed units will be sufficient for guidance in determining the well casing size. This is especially true in the case where type of pump approaches the limit of hydraulic duty generally considered proper for an efficient conventional deep well centrifugal.

If, through inadvertence, the selected casing diameter is relatively small, the pump, because of space limitations, may be thrown into the mixed flow, angle flow or propeller type. These types have their place in the scheme of vertical pumps but, in cases where the total head is of any appreciable amount, they are not as economical as the conventional deep well centrifugal. Aside from the question of economics there is also the subject of the characteristics of the head, capacity and brake horsepower values, which at "shut-off" head are sometimes high enough to endanger a motor or, in the case of thrust, may at closed valve operation impose terrific overload on the thrust bearing. This is especially true in the screw pump or propeller type pump.

In general, we recognize the complexity of a well water supply problem and we know that there are many features that are in themselves obscure and intricate, and that many of them have been rendered so by affected refinements. The prejudices of competition, and even the seller's own prejudices, make it difficult at times to show with clarity the genuine virtues of the object in question.

The character of the technical knowledge required for the selection of the proper water system is legible, it is true, but because of complexity it is not plain enough to enable all those who run to read.

In considering any complex matter we should examine every distinct factor in the composition, one by one, and reduce everything to the utmost simplicity.

In examining these factors it is necessary to compare the many features in a prospective water supply with those of a similar size and type already installed, and also with those of a dissimilar type, because discoveries may be and often are made by contrasts which would escape on a single view.

It is apparent that if all these things are true—and experiences have proved them so—then the technical knowledge required in water supply problems is not of a nature which justifies snap judgment; not because the problems involve abstract reasoning, or the solutions require a comprehensive knowledge of mathematics in the degree that astronomy demands, but, because of the multiplicity of factors, spontaneous judgment is liable to be erroneous.

Factors Affecting Pump Systems

What these factors are, their nature and their effect on the functional efficiency of a pumping system are very important, and they constitute a prelude to the technical knowledge which the writer will attempt to present.

In general, all pumps driven by vertical shafts, located in the center of a discharge pipe, are called "turbine" types because of their similarity in appearance to power-generating turbines.

There are four basic types of vertical rotating shaft pumps, each type having performance characteristics peculiar to its design.

Fig. 4 illustrates the types, any of which can be installed in a well, pit or pond, or can be arranged for use in dry-docks or to de-water mines or drain flooded areas. The field for which any one of the four types is best suited is noted in the illustration. The classification of type can be associated with the "specific speed" and wheel proportions. In the figure the final wheel diameter is designated by the letter "A" and the inlet by "B."

Ratios of $\frac{\text{"A"}}{\text{"B"}}$ are shown as co-ordinates and the values of specific speed designated as N_s are shown as the abscissa. It can be seen from the figure that the ratio of $\frac{\text{"A"}}{\text{"B"}}$ is mutually related to the "specific

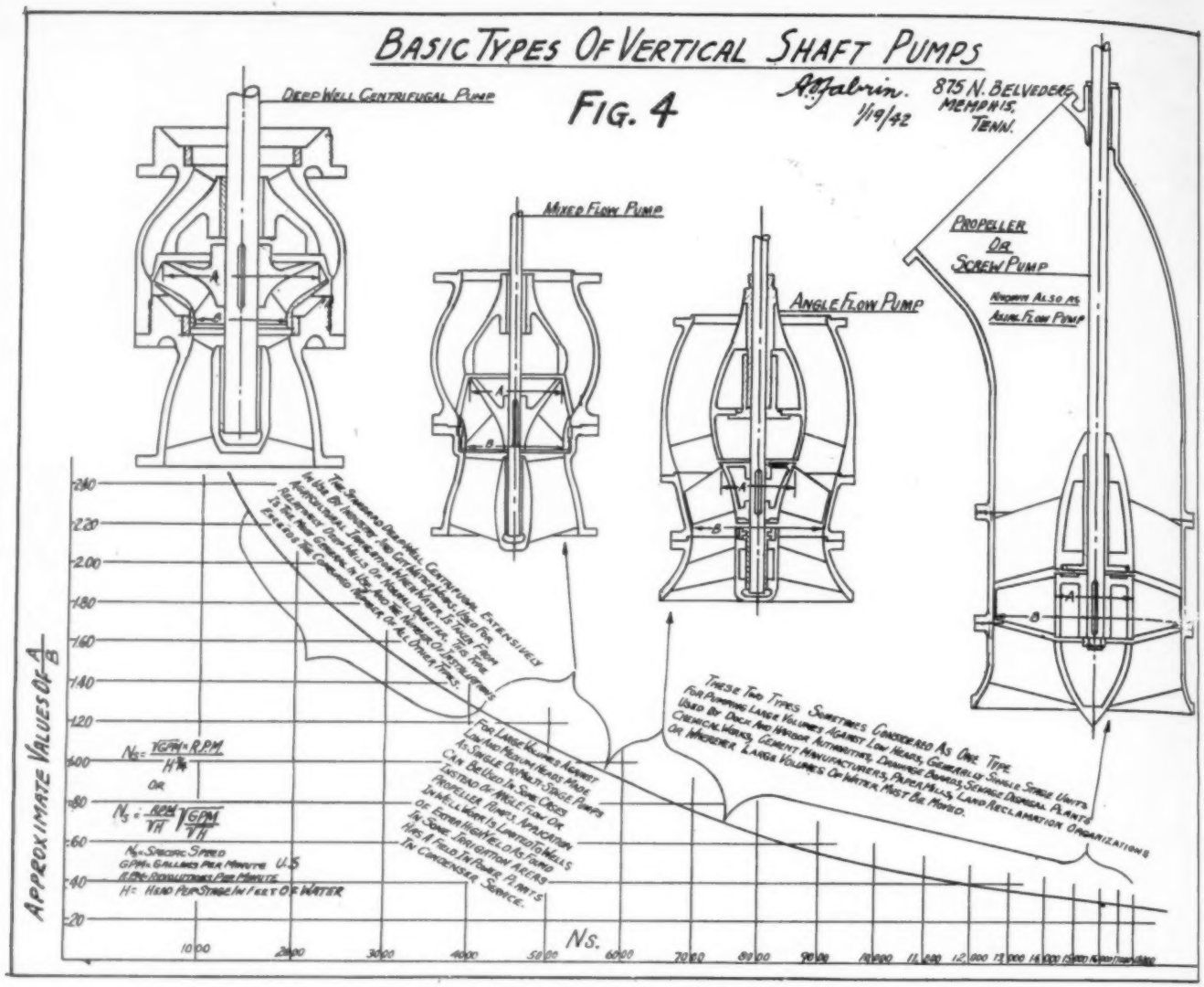

BASIC TYPES OF VERTICAL SHAFT PUMPS
FIG. 4
A. J. Fabrin. 1/19/42
875 N. BELVEDERE MEMPHIS, TENN.
DEEP WELL CENTRIFUGAL PUMP
MIXED FLOW PUMP
ANGLE FLOW PUMP
PROPELLER OR SCREW PUMP
APPROXIMATE VALUES OF A/B
Ns.
THESE TWO TYPES SOMETIMES CONSIDERED AS ONE TYPE
FOR LARGE VOLUMES AGAINST LOW HEADS
FOR LARGE VOLUMES AGAINST LOW AND MEDIUM HEADS MADE AS SINGLE OR MULTI-STAGE PUMPS CAN BE USED IN SOME CASES INSTEAD OF ANGLE FLOW OR PROPELLER PUMPS. APPLICATION OF ELBOW WORK IS LIMITED TO WELLS OF EXTRA HIGH LIFT AS FOUND IN SOME IRRIGATION AREAS
Ns = SPECIFIC SPEED
GPM = GALLONS PER MINUTE U.S.
R.P.M. = REVOLUTIONS PER MINUTE
H = HEAD PER STAGE IN FEET OF WATER

Fig. 4—Basic Types of Vertical Shaft Pumps

speed" and this relationship is illustrated by the curve.

$\frac{A}{B}$

The values of —— in relation to N_s as

$\frac{A}{B}$

shown may differ slightly on pumps made by various firms and may even differ in a line of pumps made by one company, but in the main this can be considered a mean curve and serves to illustrate the subject.

$\frac{A}{B}$

The ratio —— varies inversely with the

$\frac{A}{B}$

value N_s and this ratio is greatest where N_s is lowest. As the ratio becomes progressively smaller the accompanying values of N_s become larger. Each of the basic types shown in the illustration covers a certain range, limited by the indicated values.

For the deep well centrifugal the ratio $\frac{A}{B}$ is relatively high and N_s is low. When the specific speed Ns has increased

$\frac{A}{B}$

to 4100 and —— has been diminished to

$\frac{A}{B}$

1.25 the mixed flow type is indicated. This type of pump can be employed till the Ns has been increased to 5800 where the

$\frac{A}{B}$

ratio —— has dropped to below one. As

$\frac{A}{B}$

can be seen from the figures a continued

$\frac{A}{B}$

decrease of —— and a corresponding pro-

$\frac{A}{B}$

gressive increase in N_s indicates the next type as the angle flow and finally the largest value of N_s, and the smallest ratios of $\frac{A}{B}$ ——terminate in the propeller or screw pump.

In a collection of deep well centrifugals of different sizes but similar design, favorable efficiencies are obtained for a certain combination of capacity, head per stage and revolutions per minute, and these three variables can be expressed in one term known as the "specific speed." The best efficiency is realized when the singular value of N_s is 2500, and pumps will be relatively less efficient when designed to operate either above or below N_s 2500.

The formula used to derive the "specific speed" is given on Fig. 4, but calculation will not be necessary since charts covering capacity and head for various revolutions per minute show the value N_s.

Though the figure covers four types, the subject under discussion is the deep well centrifugal, and the other types are presented as illustrations only.

While the most favorable designs on deep well turbines are realized at specific speeds around 2500, it will be noted that the complete range for design is from a minimum of 1500 N_s to a maximum of 4100 N_s.

PART II

Methods of Selecting Pumps

To name the modern makes of deep well pumps on the market is relatively simple and to describe their merits, both actual and affected, is somewhat laborious, but the best criterion for judgment on pumping machinery is the behavior of a pump under actual service conditions. A deep well pump handles water in its raw state, just as it exists in the native water-bearing strata. Since the water in these strata must percolate or travel through various formations, it follows that the quality or composition of the water is affected by the vegetation and minerals through which it must pass. Since ground waters may originate many miles away from the well, the type of vegetation at origin differs from that at the well site, and the water in passing through the decomposed vegetation absorbs carbonic and traces of other acids which increases its power of solution

and enables it to attack mineral matter which would otherwise be insoluble.

It is obvious that there are myriads of combinations possible because of natural phenomena, but from observation it appears that the amount of residual carbon dioxide gas (CO_2) can be used as a measure in estimating the life of iron and steel used in pump construction, since CO_2 will tend to affect the iron just as it did the minerals in the earth structure. For these reasons the life of deep well pumps cannot be set at any specific number of years unless the corrosivity of the water is known or can be predicted with reasonable certainty.

In considering the functional efficiency of a deep well supply system, the factors to be considered are CO_2 content, the size of well and pump, hours of operation, cost of power and purchase price.

Functional efficiency is not measured by numerical values but a high degree of the quality is reflected in economical performance with a minimum operative attention throughout a long life of dependable service with a minimum of repairs.

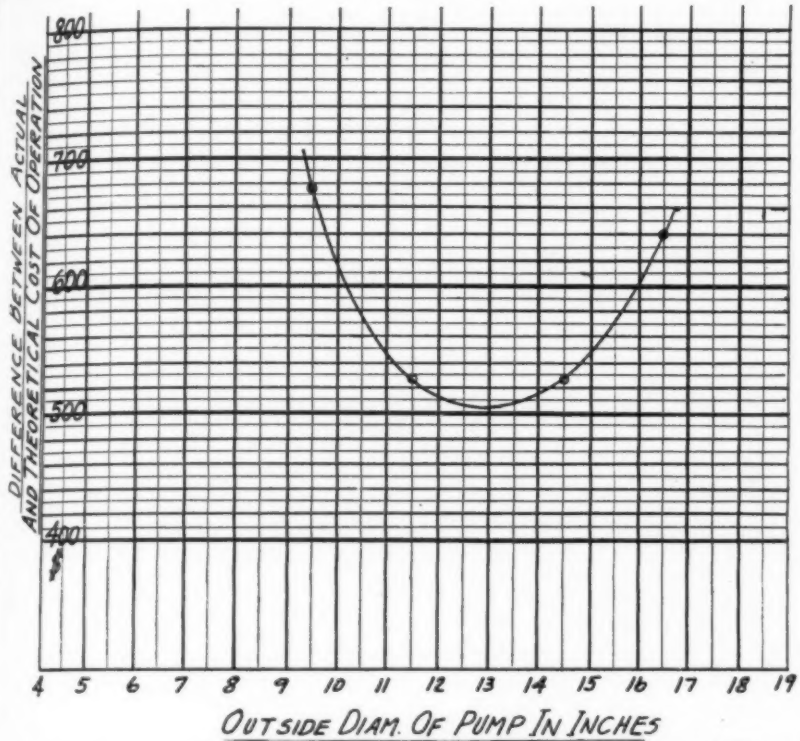

DIFFERENCE BETWEEN ACTUAL AND THEORETICAL COST OF OPERATION
800
700
600
500
400
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
OUTSIDE DIAM. OF PUMP IN INCHES

Fig. 5. Chart Showing Difference in Cost of Operation Between Actual and Theoretical Pumps of Different Sizes.

(Conditions—1000 gpm., 260 ft. field head, 1750 rpm.; operation 12 hrs. a day, 365 days or 4380 hr. per yr. with power at 1 cent per kwh.)

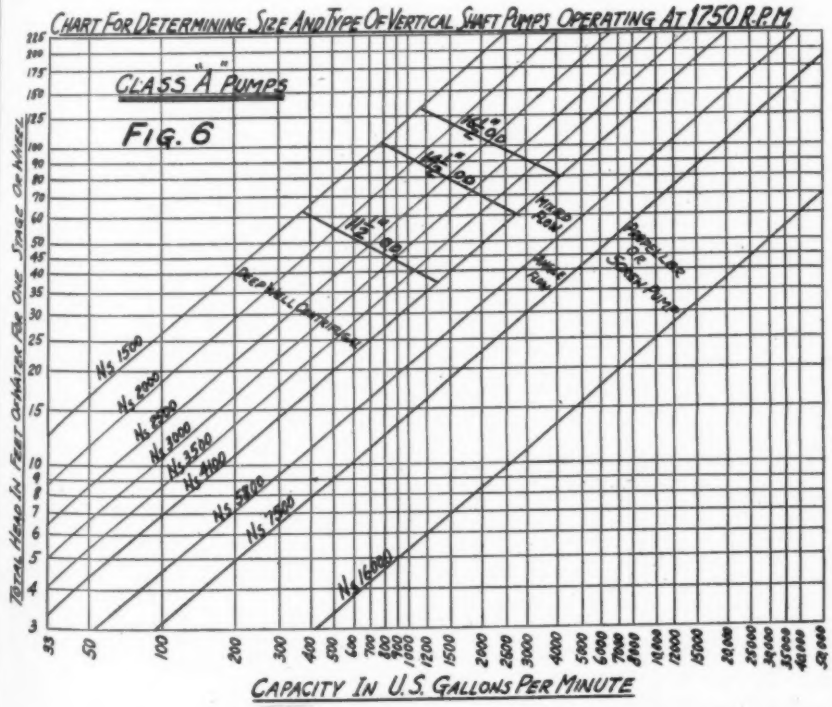


CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 1750 R.P.M.
CLASS "A" PUMPS
FIG. 6
TOTAL HEAD IN FEET OR WATER PER ONE STAGE OR WHEEL
Ns 1500
Ns 2000
Ns 2500
Ns 3000
Ns 3500
Ns 4000
Ns 5200
Ns 7000
Ns 10000
DEEP WELL CENTRIFUGAL
MIXED FLOW
PROPELLER OR SCREW PUMP
AXIAL FLOW
50 100 200 300 400 500 600 700 800 900 1000 1200 1500 2000 2500 3000 4000 5000 6000 7000 8000 10000 12000 15000 20000 25000 30000 35000 40000 50000
CAPACITY IN U.S. GALLONS PER MINUTE

Fig. 6. Chart for Determining Size and Type of Class "A" Vertical Shaft Pumps Operating at 1750 rpm.

Choice of Pump Size

Articulated study on the combined subject of wells and pumps, with due respect for the various factors mentioned, indicates that pumps of preferential diameter when installed in wells of complimentary proportions will in most cases perform at optimum efficiencies that insure a high degree of functional efficiency. The deep well centrifugal is made in a number of sizes to furnish water in various quantities, but a given capacity, motor speed, and specific speed does not necessarily mean that only one diameter of pump can be utilized. For example, a 1350 gpm. pump operating at 1750 rpm. and designed for a "specific speed" of approximately N. 1850, can be either 16½ in. in diameter or 14½ in.

The 16½-in. pump will be the most efficient, since the water passages are not crowded and the annular space between the rim of the moving impeller and the stationary walls of the case permit a favorable path for negative accelerations of the absolute velocity of water leaving the impeller. Such a design will result in a machine which the writer has designated as Class "A" and it will develop optimum efficiency.

The 14½-in. pump will have more confined passages, a narrower annular space between impeller and case, and a relatively high angle of water impingement against the walls of the stationary case. This condition favors what has been termed "impingement corrosion." Such a design will not produce a pump of optimum efficiency and has been categoried by the writer as Class "C."

Annular Space

The subject of annular space proportions beyond the moving impeller periphery becomes interesting, since it determines how close we approach the ideal conditions of flow which permit the maximum efficiency in converting the true absolute water velocity leaving the impeller into the pressure head. The ideal conditions utilize the principle of the constancy of the moment of momentum.

In considering this principle of design, and neglecting friction, it is axiomatic that no turning movement is transmitted to the water after it leaves the impeller and with the moment of momentum remaining constant the velocity at the outer boundaries of the annular space must be less than the true absolute velocity at the impeller, in the inverse ratio of the respective radii.

In the Class "A" pumps the annual space is larger than in the Class "C" and when this larger space is provided with stationary guide vanes whose angles of interception are correct, the conversion of velocity head during the change in direction of flow to an upward one is accompanied with a minimum of "impingement corrosion" and a maximum of hydraulic efficiency.

There is practical evidence to the effect that so-called "graphitic corrosion" or galvanic corrosion is more pronounced in small diameter pumps of Class "C," even when handling relatively neutral solutions of water because the cast iron bowls must handle higher velocities than the Class "A."

Between the limits indicated as Class "A" and "C" there may be as many sizes as fancy may dictate; in fact, sizes smaller

than "C" may be employed, but so far practice has shown that values indicated reflect contemporary design.

The example just presented pertained to two pumps of practically the same N_s value but of different diameter, in order to show the efficiency difference of 4 points in favor of the larger diameter unit.

If a well casing of minimum diameter is striven for, the pump selection will be forced to a high value of N_s and will result in a diameter about 65 per cent of that of the Class "A" or optimum pump. The small pump will be a Class "C" unit, running at an N_s of 4100. Such a pump will, for reasons presented, have a shorter life than that of the larger pumps and the efficiency will be less than that of a pump of a lower N_s—one more nearly approaching 2500 N_s.

As has been stated, pumps operating at an N_s of 2500 develop favorable efficiencies and, regardless of class, any duty that places the N_s above or below this value must be considered on the grounds of overall economics. Loss of money, due to shortened life and lowered efficiency through the use of small pumps, is often accepted because it permits the construction of a small diameter well. Since the first cost of a well is from three to five times that of a pump, the well is often crowded to minimum diameter without regard for later financial costs.

Operating Costs

If there is a choice between the two wells and pump sizes, and it can be shown that the annual savings realized by using the large size will in a reasonable time pay the extra cost of the larger well, then it will be good business to consider Class "A" pumps operating at an N_s near 2500. The cost of wasted power is fixed by the class of pump, the N_s, the number of stages and the purchase price of power.

To arrive at this cost calculate the power cost of operating an actual pump and deduct from this the power cost of a theoretically perfect pump. Data based on observations extending over a long period make possible charts that can be used in calculating the total annual cost of operation for a series of variable diameter pumps of a given hydraulic duty.

Fig. 5 has been prepared to show the difference in power cost between the actual and theoretical values of four different pump diameters, all to deliver 1000 gpm. against 260 feet of head when set in a well to a depth of 150 feet and operating at 1750 rpm.

The curve is based on 12 hours a day operation, 365 days a year, with power purchased at 1c per kwh. The four pumps in the example are designed to operate in wells 10-12-15-18 inches in diameter and 500 feet deep.

Table I, from which values were taken to plot the curve, shows the difference in power cost between the practical and theoretical pumps for each size:

TABLE I

I.D. of Wells and Nominal Pump Size	O.D. of Pumps	Annual Difference Between Power Costs of an Actual Pump and a Theoretically Perfect Unit
10	9½	$674.52
12	11½	525.60
15	14½	525.60
18-17	16½	639.48

From the figures in Table I which apply only to the hydraulic conditions given, it would appear that the 12-in. or 15-in. pumps would make an even choice.

Both pumps could be purchased for approximately the same price, and in fact all four pumps could be purchased for essentially the same money. But since the wells cost from three to five times that of pumps, the question is: Would it pay to construct a 12-in. or 15-in. well even though sufficient water could be procured from a 10-in. well?

The cost of constructing wells can and does resolve itself into a subject of debate. The price will vary with the type of well, the method of construction, the kind of strata encountered and many other features so familiar to a well expert. But if all these conditions are known and the only difference between the wells is diameter, then a value can be assumed which will cover the extra cost per foot for every inch increase in size of one well casing over another.

In the example chosen for illustration this value of cost difference has been arbitrarily set at 40c per inch of diameter for every foot of depth. The difference between costs of successive well sizes, 500 feet deep, will be as follows:

Well Costs Between	Difference in Cost
10 and 12	$400.00
12 and 15	600.00
15 and 18	600.00

A table can be prepared showing the difference in cost of wasted power between two pumps of varying diameter, and the difference in cost of the wells. From these

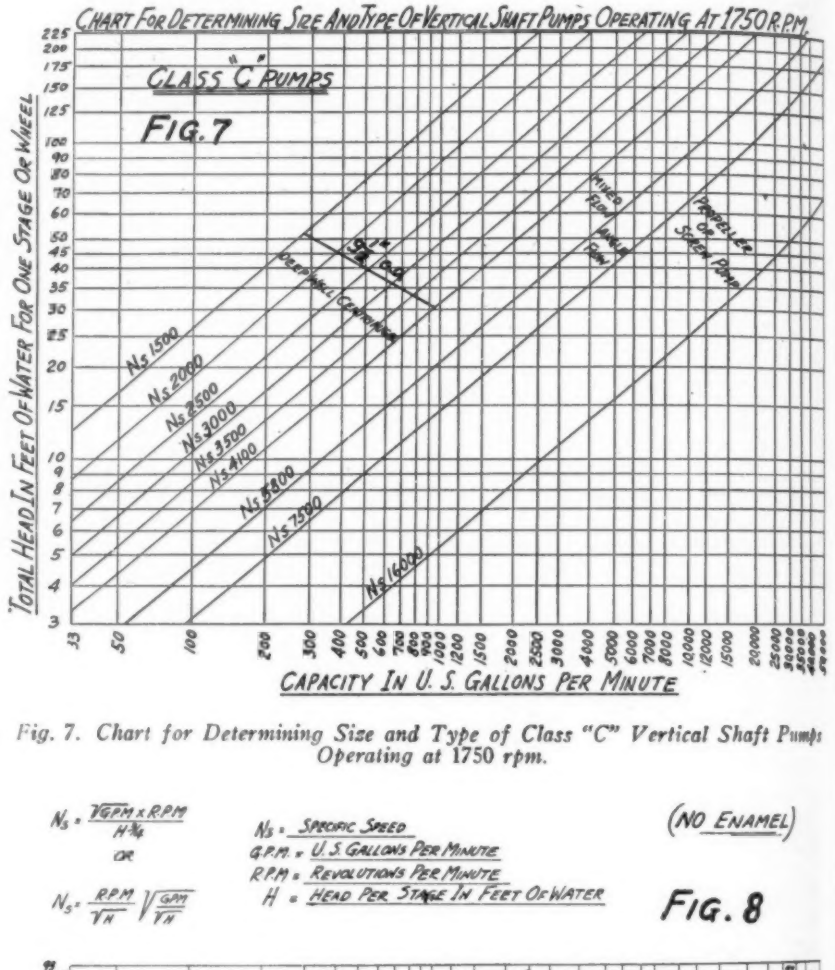


Fig. 7. Chart for Determining Size and Type of Class "C" Vertical Shaft Pumps Operating at 1750 rpm.

$$N_s = \frac{\text{GPM} \times \text{RPM}}{H^{3/4}} \quad \text{OR} \quad N_s = \frac{\text{RPM}}{\sqrt{H}} \sqrt{\frac{\text{GPM}}{\sqrt{H}}}$$

N_s = SPECIFIC SPEED
G.P.M. = U. S. GALLONS PER MINUTE
R.P.M. = REVOLUTIONS PER MINUTE
H = HEAD PER STAGE IN FEET OF WATER

(NO ENAMEL)

FIG. 8

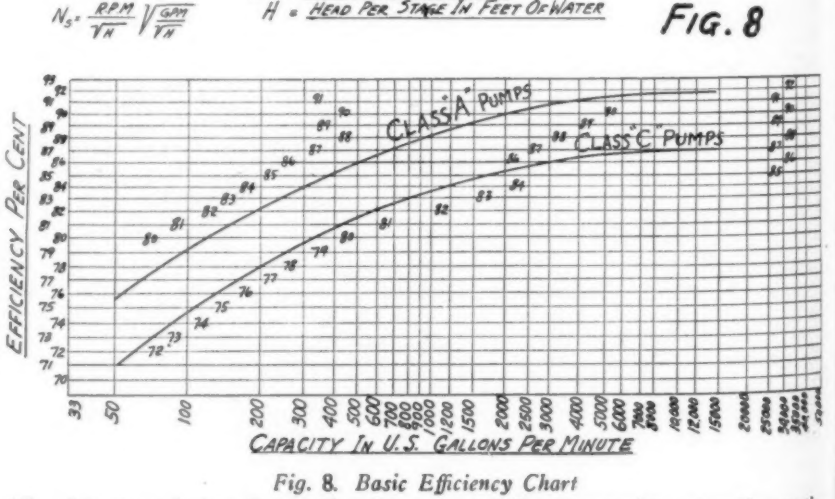


Fig. 8. Basic Efficiency Chart
(For five-stage deep well centrifugal pumps of different capacities operating at the specific speed of 2500)

data can be determined the time in years for the saving in operating power cost of the larger pump over the smaller to pay for the higher priced well. Such a table (Table II) may be designated as a recapitulation.

based on 1750 rpm. and are presented to support the examples used in illustrating the text.

Values of efficiency for pump selection are determined through the means of two charts (Fig. 8 and 9) and Table VII.

TABLE II

Recapitulation Table

Difference in Cost of Wasted Power	Difference in Well Cost	Years of Operation of One Size to Pay for Extra Cost of Another	Remarks
Between 10-in. and 12-in. Pump=$148.92 in favor of 12-in. pump	Between 12-in. and 10-in. $400.00 more for 12-in. well	$\frac{400}{148.92}$ = 2.7 years of 12-in. pump operation to pay for extra cost of a 12-in. well over 10-in.	12-in. pump and well is the logical selection
Between 12-in. and 15-in. Pump = No difference	Between 15-in. and 12-in. $600.00 more for 15-in. well	15-in. well and pump will not show favorably	15-in. pump and well should not be considered
Between 15-in. and 17-in. Pump=$113.88 in favor of 12-in. pump	Between 18-in. and 15-in. $600.00 more for 18-in. well	17-in. pump and 18-in. well — Neither well or pump favorable	17-in. pump and 18-in. well should not be considered

The effect of efficiency on costs has been illustrated by table and graph and the description and illustration of pump types have been presented in Fig. 4 accompanying Part I of this article, but the method of procedure whereby the costs have been calculated may prove interesting. Four calculation sheets showing the detail of this item are presented as tables III, IV, V, and VI, pertaining to the units on which the cost analysis in curve, Fig. 5 and Table I, have been used.

Charts that limit the selection and prescribe values are indeed of the essence in selecting pump sizes, and without such means all of the matter presented in our considerations would be without support, and could be relegated to the category of trite repetitions of the obvious and self evident.

Charts for finite pump speeds have been prepared and two such charts (Fig. 6 and 7) are presented, one for Class "A" and one for Class "C" pumps. Both are

Fig. 8 is termed the "Basic Efficiency Chart" and the two curves delineated thereon denote efficiencies for Class "A" and "C" five-stage pumps for various capacities operating at N_s 2500.

Fig. 9 is the "Specific Speed Factor Chart" which determined the factor by which the basic efficiency must be multiplied to obtain the efficiency for specific speeds other than N_s 2500. Three curves are illustrated to accommodate the quality of workmanship in finishing the impellers.

It will be noted that efficiency is materially affected by workmanship. The effect on the final efficiency by stage variation is prescribed in Table VII.

After modifying the basic efficiency of a five-stage pump by the specific speed factor, locate this value in the five-stage column in Table VII and project horizontally to the column for the number of stages under consideration.

The exact value of the "modified basic efficiency" may not be found in the five-stage column but by locating the nearest value it will be possible by interpolation to determine the final efficiency.

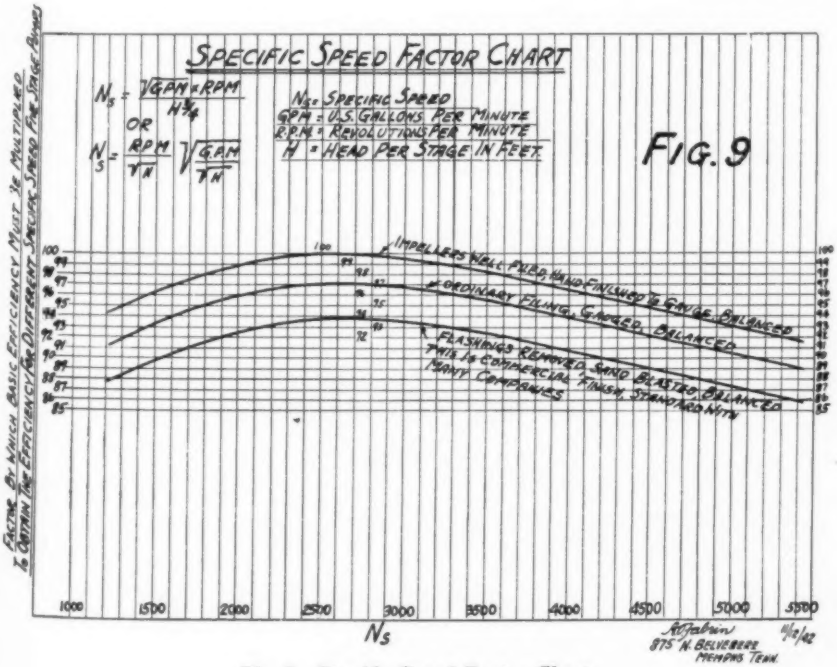


Fig. 9. Specific Speed Factor Chart

Conclusions

In conclusion, the writer wishes to state that this seemingly hypothetical method of pump selection is not the result of abstract reasoning but rather is based on the observation of thousands of deep well pumps. The performance of many modern units now in operation in cities and industries confirm and sustain the values which the pronosed procedure predicates.

No consideration has been given to porcelain enamel pumps and it is admitted that temporary increases of from 1 to 4 points can be obtained by the use of this finish. The state of the art in pump manufacture questions a complete and indiscriminate endorsement of this practice on all pumps.

The useful life of deep well pumps is materially affected by the corrosiveness of water, and since ground water varies in composition, one locality will present problems distinctly different from that of another.

Mechanical failure due to structural defects or variations in design or improper installation also affect the life of pumps.

In fact, the influence of these factors is of such importance that they justify more than passing mention and warrant a complete discussion solely devoted to the subject.

The method set forth in this paper regards only the hydraulic performance and the propositions have been proved true to fact in many installations of both small and large pumps.

Five large units recently made for a synthetic rubber plant, designed for 11,000 gpm. and total heads of 160 feet operating at 1170 rpm., developed efficiencies that complement the procedure outlined in this text. These pumps were two-stage machines with outside diameters of 27⅞ in.

In another instance fifteen 30½-in. O.D. units, each designed as single-stage pumps to deliver 13,000 gpm. at 133 feet total head operating 1200 rpm., likewise complemented this test.

These designs executed by the writer and many others covering pumps of different sizes have proven the practicability of the proposed method of pump selection.

Basing a conclusion on over 10,000 installed units indicates that the majority of requirements can be efficiently served by pumps where "specific speed" per stage ranges from approximately 2000 to 3000.

This does not mean that pumps of higher N_s values do not have a field of operation. There are circumstances wherein wells are repaired by liners inserted in the upper casing to blank off sections where corrosion or other causes have punctured the original structure. A liner of small diameter properly secured will save an expensive well and the final cost, even when using a small pump, will be less than if a complete new well were constructed.

It is believed that an investigation of installed deep well turbine pumps will substantiate the methods proposed in this paper. Aside from proving its validity by comparison with installed units, it is hoped that, by selecting sizes for new projects with respect for optimum performance, better results and greater economy will flow to the users of well water.

TABLE III

Calculation Sheet for 10-in. Pump

Capacity, U. S. gpm., 1000 — Field Head, ft., 260 — R.p.m., 1750
Setting to Top of Bowl, ft., 150 — N_s for One Stage, 4350
Size Pump, 10-in.; Class "C," 4100 — Number of Stages, 9
Column Size, 8-in. — Line Shaft Size, 1 11/16-in.
Size Motor—100 hp. — Phase 3 — Cycle 60

Computation of Head		Computation of Customer's Cost	
Surface to Pumping Level	= 105.00 ft.	Motor	= $ 936.00
Head Above Surface	= 155.00 ft.	Disch. Casting	= 115.00
Sum = Field Head	= 260.00 ft.	Column	= 700.00
Add to Field Head Friction in 150-ft. Column	= 5.85 ft.	Pump Bowl	= 570.00
Sum of Field Head and Column Friction Lab. or Total Dynamic Head	= 265.85 ft.	Total	$2321.00
Laboratory Efficiency	= 8.22%		

Computation of Horsepower

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 265.85 \text{ TDH.}}{3960}\right)}{82.2 \text{ Lab. Eff.}}\right] = 81.70 \text{ hp.}$$

Hp. Loss in 150 ft. 1 11/16-in. Shaft = 2.15 hp.

Sum = Field hp. = 83.25 hp.

Calculation of Field Efficiency

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 260 \text{ Field Hd.}}{3960}\right)}{83.85 \text{ Field Hp.}}\right] = 78.4\%$$

Calculation of Wire to Water Efficiency

Wire to Water Eff.
78.4 Field Eff. × 90 Motor Eff. = 70.5%

Calculation of Power Costs

Cost per Hour of Actual Operation

$$\left(\frac{1000 \text{ gpm.} \times 265.85 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw Hr.}}{70.5 \text{ Wire to Water Eff.}}\right) = \$0.71 \text{ per Hr.}$$

Theoretical Cost per Hour at Given Motor Eff.

$$\left(\frac{1000 \text{ gpm.} \times 265.85 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw Hr.}}{90 \text{ Motor Eff.}}\right) = \$0.556 \text{ per Hr.}$$

Difference in Cost Between Actual and Theoretical = $0.154 per Hr.
Diff. Bet. Actual and Theo. Cost of Oper. for Year of 4380 Hrs. = $0.154 × 4380 = $674.52

TABLE IV

Calculation Sheet for 12-in. Pump

Capacity, U. S. gpm., 1000 — Field Head, ft., 260 — R.p.m., 1750
Setting to Top of Bowl, ft., 150 — N_s for One Stage, 3200
Size of Pump, 12-in.; Class "A," 3000 — Number of Stages, 6
Column Size, 8-in. — Line Shaft Size, 1 11/16-in.
Size Motor—100 hp. — Phase 3 — Cycle 60

Computation of Head		Computation of Customer's Cost	
Surface to Pumping Level	= 105.00 ft.	Motor	= $ 936.00
Head Above Surface	= 155.00 ft.	Disch. Casting	= 115.00
Sum = Field Head	= 260.00 ft.	At Surface	= 700.00
Add to Field Head Friction in 150-ft. Column	= 5.85 ft.	Column	= 600.00
Sum of Field Head and Column Friction Lab. or Total Dynamic Head	= 265.85 ft.	Total	$2351.00
Laboratory Efficiency	= 86.7%		

Computation of Horsepower

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 265.85 \text{ TDH.}}{3960}\right)}{86.7 \text{ Lab. Eff.}}\right] = 77.50 \text{ hp.}$$

Hp. Loss in 150 ft. 1 11/16-in. Shaft = 2.15 hp.

Sum = Field hp. = 79.65 hp.

Calculation of Field Efficiency

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 260 \text{ Field Hd.}}{3960}\right)}{79.65 \text{ Field Hp.}}\right] = 82.5\%$$

Calculation of Wire to Water Efficiency

Wire to Water Eff.
82.5 Field Eff. × 90 Motor Eff. = 74%

Calculation of Power Costs

Cost per Hour of Actual Operation

$$\left(\frac{1000 \text{ gpm.} \times 265.85 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw Hr.}}{74 \text{ Wire to Water Eff.}}\right) = \$0.676 \text{ per Hr.}$$

Theoretical Cost per Hour at Given Motor Eff.

$$\left(\frac{1000 \text{ gpm.} \times 265.85 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw Hr.}}{90 \text{ Motor Eff.}}\right) = \$0.556 \text{ per Hr.}$$

Difference in Cost Between Actual and Theoretical = $0.120 per Hr.
Diff. Bet. Actual and Theo Cost of Oper. for Year of 4380 Hrs. = $0.120 × 4380 = $525.60

PART III

Anticipating Ground Water Level Recession

INDISPENSABLE and expendable resources approach near exhaustion when the principles of conservation are ignored, misunderstood or misinterpreted. Water is one of these resources which is supplied by nature in quantities governed by irrevocable laws that are and have been essentially uniform through the ages.

The popularity and increased employment of wells and pumps in public utility and industrial fields has put unprecedented demands upon ground water supplies. From records it appears that because of vigorous pumping, demands are greater than the natural supply, and statistics on the trend of ground water levels in many sections of the United States point to a decided need for legislation to control well construction and regulate operation.

Men in close touch with the situation realize that in the arid and semi-arid regions of this country human life and industry to a great extent depend upon well water for their existence, and that if by reason of deep water levels the pumping costs become prohibitive, future development is questionable and may become impossible. Population and industry, being mutually associated, then become static. To the states belong the duty of prescribing specific laws on ground water conservation in their particular confines, with due respect for bordering states which might be injured by too ambitious limitations. Perhaps general laws relative to interference of one state with another as regards water depletion belong to the Federal Government, but certainly not the detail organization within the states.

There is a special reason for making this statement, and the basis for it is found in the first annual report of the U. S. Geological Survey published in 1900. Reference to this will be made later. The gradual lowering of the ground water table cannot be traced to any one cause but is rather the result of economic expansion in its many phases. This expansion affects the natural underground reservoirs from which wells get their supply and also affects the surface streams. It changes the characteristics of rivers, often engendering flash floods in seasons which in the past were without floods.

Lakes have been known to become dry because their sources of supply, which were springs or flowing wells, no longer conveyed the water from the former water level near the ground surface. Some of the north midwestern states which have become deservedly famous for their beautiful retreats have actually had to resort to deep well pumping as the source of supply of water to maintain and perpetuate lake levels.

Causes of Ground Water Recession

Opinions on the causes of ground water recession differ. There is no denial that the causes are several, but the degree in which each cause affects the whole has been the subject of debate.

The source of all fresh water supply existing either in the ground or on the surface is precipitation in the form of rain or melting snows. In the case of ground water the supply enters at locations where the layers or strata of the earth bend or tilt upwards so that the ends of the forma-

TABLE V

Calculation Sheet for 15-in. Pump

Capacity, U. S. gpm., 1000 — Field Head, ft., 260 — R.p.m., 1750
Setting to Top of Bowl, ft., 150 — N_s for One Stage, 1930
Size Pump, 15-in.; Class "A," 2000 — Number of Stages, 3
Column Size, 10-in. — Line Shaft Size, 1 11/16-in.
Size Motor—100 hp. — Phase 3 — Cycle 60

Computation of Head

Surface to Pumping Level	= 105.00 ft.
Head Above Surface	= 155.00 ft.
Sum = Field Head	= 260.00 ft.
Add to Field Head Friction in 150-ft. Column	= 1.50 ft.
Sum of Field Head and Column Friction Lab. or Total Dynamic Head	= 261.50 ft.
Laboratory Efficiency	= 85.12%

Computation of Customer's Cost

Motor	= $ 936.00
Disch. Casting at Surface	= 141.50
Column	= 900.00
Pump Bowl	= 600.00
Total	= $2577.50

Computation of Horsepower

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 261.50 \text{ TDH.}}{3960}\right)}{85.12 \text{ Lab. Eff.}}\right] = 77.50 \text{ hp.}$$

Hp. Loss in 150 ft. 1 11/16-in. Shaft = 2.15 hp.

Sum = Field hp. = 79.65 hp.

Calculation of Field Efficiency

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 260 \text{ Field Hd.}}{3960}\right)}{79.65 \text{ Field Hp.}}\right] = 82.5\%$$

Calculation of Wire to Water Efficiency

Wire to Water Eff.
82.5 Field Eff. × 90 Motor Eff. = 74%

Calculation of Power Costs

Cost per Hour of Actual Operation

$$\left(\frac{1000 \text{ gpm.} \times 261.50 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw. Hr.}}{74 \text{ Wire to Water Eff.}}\right) = \$0.667 \text{ per Hr.}$$

Theoretical Cost per Hour at Given Motor Eff.

$$\left(\frac{1000 \text{ gpm.} \times 261.50 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw. Hr.}}{90 \text{ Motor Eff.}}\right) = \$0.547 \text{ per Hr.}$$

Difference in Cost Between Actual and Theoretical = $0.12 per Hr.
Diff. Bet. Actual and Theo. Cost of Oper. for Year of 4380 Hrs. = $0.12 × 4380 = $525.60

TABLE VI

Calculation Sheet for 17-in. Pump

Capacity, U. S. gpm., 1000 — Field Head, ft., 260 — R.p.m., 1750
Setting to Top of Bowl, ft., 150 — N_s for One Stage, 1420
Size Pump, 17-in.; Class "A," 1500 — Number of Stages, 2
Column Size, 10-in. — Line Shaft Size, 1 11/16-in.
Size Motor—100 hp. — Phase 3 — Cycle 60

Computation of Head

Surface to Pumping Level	= 105.00 ft.
Head Above Surface	= 155.00 ft.
Sum = Field Head	= 260.00 ft.
Add to Field Head Friction in 150-ft. Column	1.50 ft.
Sum of Field Head and Column Friction Lab. or Total Dynamic Head	= 261.50 ft.
Laboratory Efficiency	81.5%

Computation of Customer's Cost

Motor	= $ 936.00
Disch. Casting at Surface	= 141.50
Column	= 900.00
Pump Bowl	= 600.00
Total	$2577.50

Computation of Horsepower

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 261.50 \text{ TDH.}}{3960}\right)}{81.5 \text{ Lab. Eff.}}\right] = 81.00 \text{ hp.}$$

Hp. Loss in 150 ft. 1 11/16-in. Shaft = 2.15 hp.

Sum = Field hp. = 83.15 hp.

Calculation of Field Efficiency

$$\left[\frac{\left(\frac{1000 \text{ gpm.} \times 260 \text{ Field Hd.}}{3960}\right)}{83.15 \text{ Field Hp.}}\right] = 79\%$$

Calculation of Wire to Water Efficiency

Wire to Water Eff.
79 Field Eff. × 90 Motor Eff. = 71%

Calculation of Power Costs

Cost per Hour of Actual Operation

$$\left(\frac{1000 \text{ gpm.} \times 261.50 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw. Hr.}}{71 \text{ Wire to Water Eff.}}\right) = \$0.694 \text{ per Hr.}$$

Theoretical Cost per Hour at Given Motor Eff.

$$\left(\frac{1000 \text{ gpm.} \times 261.50 \text{ TDH.} \times .0001884 \times .01 \text{ Rate per Kw. Hr.}}{90 \text{ Motor Eff.}}\right) = \$0.548 \text{ per Hr.}$$

Difference in Cost Between Actual and Theoretical = $0.146 per Hr.
Diff. Bet. Actual and Theo. Cost of Oper. for Year of 4380 Hrs. = $0.146 × 4380 = $639.48

tion act as collectors. The outcropping layers are invariably covered with vegetation and this area is commonly called a watershed.

Excess water that does not enter the earth at the outcrop drains down the surface slopes and is called run-off water. The water that thus flows to the creeks and rivers is diminished by evaporation and percolation into the top soil over which it passes.

Most large rivers originate in forest areas or areas of rock outcrop. As they journey to the sea, drainage from hills and mountains arrives at the river after flowing over the plains, which for centuries have been areas of aggregation built up by residual soil, deposited by the run-off water from the hills.

The rich soil lying near the river is punctuated by shallow depressions filled with land-locked water forming swamps. While swamps are the natural habitat of insects, which in many cases cause fever and other human misery, they also serve as recharging means whereby moisture can slowly percolate into the soil. The richness of the soil near rivers lures agriculture. Because of this, swamps and lowlands are drained, quickening the run-off and delivering to the rivers great quantities of water, sometimes in volume that the rivers cannot handle immediately, and thus we have overflows or floods. It seems reasonable to believe that the drainage systems have affected somewhat the underground storage, but this factor alone cannot be said to have a major influence. The immediate benefits derived from the rich drain soil far outweigh physical discomforts which would accrue if the land were allowed to revert to swamps.

Forest fires and indiscriminate timber cutting have done much to destroy the blanket or mat of leaves or other vegetation which earlier acted as a sponge that retained the moisture and allowed slow percolation into the soil.

The Need for Governmental Regulation

The subject of ground water origin and the variation in underground levels is indeed a highly specialized subject and these few remarks are intended to illustrate that the fundamental changes in pumping levels from year to year are not under the immediate control of well water users. Because of increased pumping cost due to receding levels, the future will perhaps invite favorable regulations relative to the number and capacity of wells permissible in a given area. It is, of course, understood that such regulations should not be arbitrary, but in each district or area must be peculiarly adapted to the geological conditions governing the water supply in that area.

It is reasonable to believe that control will be indexed to geological conditions, but it is interesting to note that government regulations do not always follow natural laws. It is easier to issue blanket rules and follow precedent. The first annual report of the U. S. Geological Survey published in 1900 suggests the fallacy of such procedure when it reveals that the government surveyors, when determining the boundaries of western land division, merely were concerned with square or rectangular plats, all of essentially equal size, extending to regions that had no access to the run-off surface water near the mountains. Up until the time when the development of ground water supply and deep well pumping was well under way, settlers often found that they

TABLE VII

Efficiency Corrections for Various Stages*

Number Stages								
1	2	3	4	5	6	7	8	9
50	....	....	....	....	....	....	....	....
51	....	....	....	....	....	....	....	....
52	....	....	....	....	....	....	....	....
53	....	....	....	....	....	....	....	....
54	....	....	....	....	....	....	....	....
55	....	....	....	....	....	....	....	....
56	57.5	58.5	59.5	60	60.5	60.5	60.5	60.5
57	58.5	59.5	60.5	60.5	61	61	61	61
58	59.5	60.5	61.5	61.7	62	62	62	62
59	60.7	62	62.7	62.9	63.2	63.2	63.2	63.2
60	62	63	64	64.2	64.5	64.5	64.5	64.5
61	62.7	64	64.7	64.9	65.5	65.5	65.5	65.5
62	63.5	65	65.5	66	66.5	66.5	66.5	66.5
63	65	66	67	67.5	68	68	68	68
64	66	67.2	68	68.5	69	69	69	69
65	67	68.5	69	69.5	70	70	70	70
66	67.6	69	70	70.5	71	71	71	71
67	68.6	70.2	71	71.5	72	72	72	72
68	69.5	71	71.9	72.5	73	73	73	73
69	70.7	72	72.7	73.5	74	74	74	74
70	71.5	73	74	75	75.5	75.5	75.5	75.5
71	73	74.5	75.2	76	76.5	76.5	76.5	76.5
72	74	75.2	76.5	77	77.6	77.6	77.6	77.6
73	75.2	76.7	77.5	78	78.5	78.5	78.5	78.5
74	76	77.5	78.4	79	79.5	79.5	79.5	79.5
75	77.2	78.7	79.6	80.2	80.9	80.9	80.9	80.9
76	78	79.5	80.7	81.5	82	82	82	82
77	79	80.7	81.6	82.5	83	83	83	83
78	80	81.5	82.5	83.4	84	84	84	84
79	81	82.5	83.5	84.2	85	85	85	85
80	82	83.5	84.5	85	86	86	86	86
81	83	84.5	85.7	86.2	87	87	87	87
82	84	85.5	87	87.5	88	88	88	88
83	85	86.5	88	88.5	89	89	89	89
84	86	88	89	90	90.5	90.5	90.5	90.5
85	87	89	89.8	90.5	91	91	91	91
86	88	89.5	90.5	91.5	92	92	92	92

*As revised Feb. 11, 1944. Original 1-19-42.

were located in essentially desert land and, in order to secure water, were put to great expense and endless litigation over water rights. The method and plan of western land subdivision were under the supervision of surveyors whose past experience had been confined to similar work in the humid and semi-humid areas of the east and midwest where surface water was extant and plentiful, since precipitation was generally uniform.

It will always be a matter of conjecture as to what would have been the degree of western land development if deep well pumping had never been instituted, but it is modest to venture the statement that wells and pumps prevented the unintentionally erroneous principles of land subdivision from becoming a matter of serious consequence. Irrespective of geographic locations, large cities and industries are naturally regions of dense population, and when their water supply comes from wells, the concentrated demand upon the ground water supply in a relatively small area becomes greater than the natural replenishment.

Therefore, in these areas the pumping elevation drops to low levels. Thereupon, even as much as twenty or thirty miles away the levels will be affected, but not as greatly as in a confined pumping area. Several cities in the United States have recognized this fact and have located their wells miles away from the city proper.

Very large cities generally depend upon surface supplies because the ground water to supply a well system cannot flow in through the strata fast enough to supply the great withdrawal demand.

Most of the data on receding ground water levels are taken from dense population centers. These observations indicate an average drop of from three to four feet a year. In general, such sections take their water supply from a strata or stratas fed by one of the continental water sheds. There are, however, countless minor water sheds which support small communities, and while the water levels lower, they recover rapidly, and since the distance from the outcrop to the wells is small, the time to replenish the depletion is shortened.

Precipitation is essentially uniform from year to year, and the amount of rainfall in humid and semi-humid sections is sufficient for human needs. A forty acre cornfield consumes as much water in a good season as a town of 3,000 people using water at the rate of 15 gallons a day per person. It cannot be argued that such a crop robs the ground water supply, since its thirst is satisfied from a depth of not more than seven feet in the earth.

It is true that some of the wild grasses have root systems that extend down twenty feet, but it cannot be said that this condition affects the ground water level.

Industrial water requirements in many instances are very heavy, and when a fairly large city composed of many workers must, besides furnishing a domestic water supply, also supply well water for a great number of factories, the pumping level will naturally be deep. Frequently industrial plants have their own well water supply and if no consideration is given to interference due to closely grouped wells, the water table throughout a considerable area will be seriously affected. This seems to be the condition prevailing in the Eastern section of the United States and to a large extent in the Midwest.

The Southwestern area of the country and a large portion of the Southwest coast lie in what is considered the arid and semi-arid zones. Unless precipitation, which is not sufficient for agriculture, is augmented by artificial irrigation, a large portion of the West would still be desert-like in character. Were it not for groundwater supplies and deep well pumps, the wonderful industrial development which is so dependent upon agricultural prosperity would indeed be nonexistent.

The West Responsible for Much Deep Well Progress

In no other section of the world will you find people of every walk in life so water-conscious as in the Southwestern United States. It is a fair assumption that in California alone you will find more water wells per square mile than in any other place on the globe. To the West and Southwest is due most of the credit for progress in improved well construction and for pump refinement developments of recent years.

Their water conservation laws and well construction regulations are the result of many years of practical experience, and while they are peculiarly adapted to the geological characteristics of their section, these laws and regulations can be of use as guides in the making of rules for the Midwest and East. Some of the states in these latter sections have completed legislation on the subject, with major emphasis directed towards some degree of control over well water supplies for industry as well as for municipalities.

Looking Ahead at Possibilities When Developing Well Supplies

Until the time arrives when water supply from wells can be controlled by regulation of industrial density, deep well centrifugal pumps should be selected which will under existing conditions serve the user over a long period before extension of the pump column becomes necessary.

In Part II it was explained by graphs and examples how deep well pumps that operated at a specific speed of approximately 2,500 per stage would, because of high efficiency, warrant the extra first cost of wells for such pumps. Now it is the intention to show that pumps of this specific speed and under also have desirable suction characteristics of great importance when ground water levels are receding.

Deep well centrifugals are generally sold under a guaranty based on conditions wherein the water level when pumping is above the lowest impeller. In a way this infers that pumps will not operate satisfactorily if the water stands below the impeller. This seeming paradox resembles somewhat the real paradox of the bumble bee, which from an aero-dynamic point of view cannot fly but does.

It is true that some deep well centrifugals will not operate unless flooded, but it is the intention to consider how in view of water level recession in wells, savings in pump column additions can be affected by the use of pumps with a specific need (Ns) of approximately 2,500. It is the intention to show that pumps operating at approximately this specific speed will, when necessary, because of their design, operate with water levels considerably below the pump proper, provided sufficient suction pipe is used. This latter characteristic will make it unnecessary to pull a pump and add suction column as frequently as might be the case with pumps of higher specific speeds (Ns).

Commercial Significance of "Specific Speed"

The commercial significance of the term "specific speed" is very real and is a key to the proper selection of deep well centrifugal pumps. The technical definition of specific speed and the part it plays in design will be neglected, since the subject under consideration is that of selecting from a group of standard commercially designed pumps (of various specific speeds) that one best suited for a particular hydraulic condition.

"Specific Speed" is not the capacity of a pump, nor its head per stage, nor the revolutions per minute, but it is these three variables combined in a proper manner and expressed in one term.

N_s FOR 1750 RPM DEEP WELL CENTRIFUGAL PUMPS
FOR HEADS FROM 5 TO 36 FEET AND CAPACITIES FROM 15 TO 1200 G.P.M.
HEAD PER STAGE IN FEET

GPM	5	6	7	8	9	10	11	12	14	16	18	20	22	24	26	28	30	33	36
15	1069	1769	1572	1428	1302	1200													
20	1348	2046	1816	1647	1505	1392	1298												
25	1630	2284	2030	1842	1683	1557	1451	1356											
30	1890	2502	2224	2018	1843	1705	1589	1486	1324										
35	2094	2720	2401	2179	1990	1841	1716	1604	1429	1294									
40	2304	2891	2568	2330	2129	1969	1835	1716	1529	1384									
45	2515	3064	2726	2471	2258	2089	1946	1820	1621	1468	1344								
50	2706	3230	2871	2605	2379	2201	2052	1918	1708	1547	1417								
55	2886	3388	3011	2732	2496	2309	2152	2012	1793	1623	1486	1373							
60	4027	3537	3144	2852	2606	2411	2247	2100	1871	1694	1551	1434	1335						
65		3683	3274	2970	2715	2510	2339	2187	1949	1764	1616	1493	1390						
70		3821	3396	3082	2815	2604	2427	2269	2022	1830	1676	1549	1442	1352					
75		3959	3515	3189	2915	2695	2512	2348	2092	1894	1735	1603	1492	1398	1318				
80		4082	3628	3292	3008	2782	2593	2424	2160	1955	1791	1655	1541	1444	1361	1286			
85			3751	3404	3102	2872	2675	2500	2228	2016	1847	1706	1589	1489	1403	1326	1258		
90			4060	3504	3195	2963	2758	2573	2292	2075	1901	1756	1635	1532	1444	1363			
95				3604	3287	3043	2840	2647	2356	2133	1955	1806	1682	1576	1485	1401	1328		
100				3704	3365	3123	2921	2721	2420	2192	2008	1852	1724	1615	1523	1437	1355		
110				4033	3684	3409	3177	2970	2646	2395	2196	2027	1887	1768	1667	1573	1494	1391	1303
120				4199	3836	3549	3308	3092	2755	2494	2289	2111	1965	1841	1736	1638	1556	1448	1357
130					3981	3685	3432	3208	2859	2588	2376	2190	2039	1911	1801	1699	1615	1503	1408
140					4123	3814	3555	3323	2961	2680	2455	2268	2112	1979	1865	1760	1672	1557	1458
150						4118	3838	3589	3197	2894	2651	2449	2280	2137	2014	1901	1806	1681	1576
160							4102	3835	3417	3093	2833	2617	2437	2284	2152	2031	1930	1796	1682
170								4068	3625	3281	3006	2778	2586	2423	2284	2155	2048	1906	1785
180									3821	3459	3168	2927	2725	2554	2407	2272	2158	2009	1882
190									4006	3626	3322	3069	2857	2678	2524	2382	2263	2106	1973
200									4186	3789	3470	3207	2986	2798	2637	2488	2364	2201	2061
225										3944	3612	3338	3108	2912	2745	2590	2461	2290	2145
250										4090	3746	3462	3223	3020	2847	2686	2552	2375	2225
275											3880	3586	3381	3168	2948	2782	2643	2460	2305
300											4018	3703	3498	3230	3045	2873	2730	2541	2380
325											4150	3820	3606	3467	3229	3048	2895	2675	2504
350												4040	3814	3612	3414	3213	3052	2841	2661
375												4062	3788	3570	3367	3201	2980	2751	
400													3957	3730	3520	3344	3112	2915	
450													4118	3882	3663	3480	3239	3034	
500														4028	3801	3611	3361	3148	
550														4176	3934	3738	3479	3259	
600															4069	3861	3594	3366	
650																3980	3704	3469	
700																4095	3902	3658	
750																	3996	3668	
800																	4078	3818	
850																		3947	
900																		4122	
1000																			
1200																			

Hazelton 1942

Table VIII. N_s Values for 1750 RPM., Head 5 to 36 Ft.

N_s FOR 1750 RPM DEEP WELL CENTRIFUGAL PUMPS
FOR HEADS FROM 40 TO 130 FEET AND CAPACITIES FROM 140 TO 8000 G.P.M.
HEAD PER STAGE IN FEET

GPM	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130
140	1302																		
150	1349	1233																	
175	1456	1331																	
200	1556	1423	1346																
225	1651	1509	1397																
250	1740	1591	1472	1370															
275	1825	1668	1543	1436	1340														
300	1906	1743	1612	1500	1400	1305													
325	1984	1814	1678	1562	1458	1379	1303												
350	2058	1881	1741	1620	1512	1430	1351	1284											
375	2131	1949	1803	1678	1566	1481	1400	1332											
400	2202	2013	1862	1733	1617	1530	1446	1376	1309										
450	2335	2134	1975	1837	1715	1622	1533	1459	1388	1325									
500	2461	2250	2082	1937	1808	1710	1616	1538	1463	1397	1338								
550	2581	2360	2183	2031	1896	1793	1695	1613	1535	1465	1404	1359							
600	2697	2465	2281	2122	1981	1873	1770	1685	1603	1530	1466	1410	1355	1308					
650	2807	2566	2374	2209	2061	1950	1843	1754	1669	1593	1526	1468	1410	1361	1314				
700	2912	2662	2463	2292	2139	2023	1912	1820	1732	1653	1583	1523	1463	1412	1364	1324			
750	3014	2755	2549	2372	2214	2094	1979	1883	1792	1711	1639	1577	1514	1462	1414	1371	1323		
800	3114	2844	2633	2450	2287	2163	2044	1945	1851	1767	1693	1629	1564	1510	1460	1416	1366	1322	
850	3209	2934	2716	2525	2357	2230	2107	2005	1908	1821	1745	1679	1612	1556	1505	1459	1408	1362	1323
900	3302	3019	2793	2599	2426	2294	2168	2063	1964	1876	1796	1727	1659	1601	1549	1502	1449	1402	1365
950	3393	3102	2870	2670	2492	2357	2228	2120	2017	1926	1845	1775	1705	1645	1591	1543	1489	1440	1402
1000	3481	3182	2944	2739	2556	2418	2285	2175	2069	1975	1892	1820	1749	1688	1632	1583	1527	1477	1439
1100	3651	3337	3088	2873	2681	2536	2397	2281	2171	2072	1985	1910	1834	1770	1712	1660	1602	1550	1509
1200	3813	3486	3225	3000	2801	2649	2504	2382	2267	2169	2078	1994	1916	1849	1788	1734	1673	1619	1571
1300	3969	3628	3357	3123	2915	2757	2606	2480	2360	2253	2158	2070	1994	1925	1861	1805	1742	1685	1641
1400	4126	3770	3488	3245	3029	2865	2708	2577	2452	2340	2242	2157	2078	2008	1934	1875	1809	1750	1705
1500		3896	3604	3354	3130	2961	2798	2663	2534	2419	2317	2229	2147	2076	1999	1938	1870	1809	1762
1650		4083	3781	3519	3285	3107	2936	2794	2659	2538	2432	2339	2247	2168	2087	2023	1962	1898	1849
1800			3950	3675	3430	3244	3066	2918	2777	2650	2539	2442	2346	2264	2180	2113	2049	1982	1930
2000			4163	3874	3616	3420	3232	3076	2927	2794	2678	2575	2473	2387	2309	2238	2160	2090	2035
2200				4063	3792	3587	3393	3226	3070	2930	2807	2700	2594	2503	2421	2347	2265	2192	2134
2400					3961	3746	3544	3368	3206	3064	2932	2821	2709	2615	2529	2452	2366	2289	2227
2600					4128	3900	3685	3501	3337	3186	3052	2936	2820	2723	2632	2553	2463	2382	2320
2800						4049	3824	3634	3463	3306	3167	3047	2926	2824	2732	2648	2556	2472	2408
3000						4189	3959	3767	3589	3422	3278	3153	3029	2923	2828	2741	2645	2559	2492
3200							4088	3890	3702	3534	3385	3257	3128	3019	2920	2831	2732	2643	2574
3500							4266	4070	3874	3699	3544	3407	3270	3156	3053	2970	2855	2763	2689
4000								4158	3950	3764	3600	3455	3314	3203	3103	3015	2894	2796	
4500									4189	4013	3860	3708	3579	3461	3356	3258	3132	3030	
5000											4070	3908	3772	3648	3537	3443	3302	3216	
5500												4099	3956	3827	3711	3601	3464	3373	
6000													4102	3948	3825	3729	3618	3528	
6500														4161	4034	3891	3764	3667	
7000															4186	4039	3908	3805	
7500																4180	4044	3938	
8000																	4187	4068	

Hazelton 1942

Table IX. N_s Values for 1750 RPM., Head 40 to 130 Ft.

Just as the letters of an alphabet combine to make words, so the three variables —capacity, head, and speed—are the components of equations which evolve the term "Specific Speed," commonly referred to as Ns value.

Small values of Ns are indexed to pumps of relatively high head per stage for a given capacity and operating at medium or low revolutions per minute. The impellers of such pumps are narrow in width, when compared to their diameter, and the impeller suction inlet diameter is also comparatively small.

Large values of Ns, in contrast with the foregoing, apply to pumps of low head for given capacity and operating at medium or high revolutions per minute. The impeller widths are essentially great and the impeller suction inlet diameter is relatively large.

The phenomenon of whirling waters exemplified in the centrifugal pump impeller follows laws which defy strict mathematical definitions or analysis. Because of this it is necessary to modify known laws by empirical factors derived from tests, or found in the field of practice. One of the several characteristics is that of suction performance, which is dependent upon atmospheric pressure. Many tests have provided empirical factors for various design types and from these data suction performance can be determined.

Impeller Characteristics and Lift Capacities

Turn for a moment to Fig. 10, illustrating an impeller of low Ns, and you will note that the diameter of the impeller is considerably larger than the so-called eye of the impeller, through which all the water must enter. The blades that "bite" into the fluid at the eye extend themselves to the outside diameter of the impeller and in doing so form long channels that guide the outward flowing streams through smooth tunnels. Such proportions are conducive to high suction lifts, which means, of course, that such an impeller will successfully and efficiently pump when the water level is well below the pump. In a way it can be imagined that long channels have a firmer grip on the flowing water and using a common expression, they will "pull water" from considerable depths.

Looking at Fig. 11, representing a high Ns impeller, we see a large eye in comparison with the diameter and blades forming short channels. This condition does not favor pumping from considerable depths below the impeller; and, in some hydraulic duties, this type of impeller requires water under a positive head at the eye in order to pump efficiently.

It must be remembered that regardless of the Ns value, all centrifugal pump bodies must be filled with water at the start of operation.

Because of the limits imposed by atmospheric pressure, the maximum distance which water can be lifted is theoretically 33⅓ feet at sea level. Friction losses, the energy required to move water and other factors limit the maximum lift to about 25 feet. But this maximum lift can be realized when certain speeds are employed. Within the limits determined by the partcular type and design, greater amounts of water can enter a pump with an increase of shaft revolutions. The upper limits on this behavior are reached when the water is considerably below the pump. Every foot of lift below the impeller reduces the net atmospheric pressure available for forcing water into the impeller eye. There comes a condition near the high suction lift region where the inlet velocity to the impeller can no longer, because of low absolute pressure, support an increase in capacity regardless of the revolutions per minute of shaft.

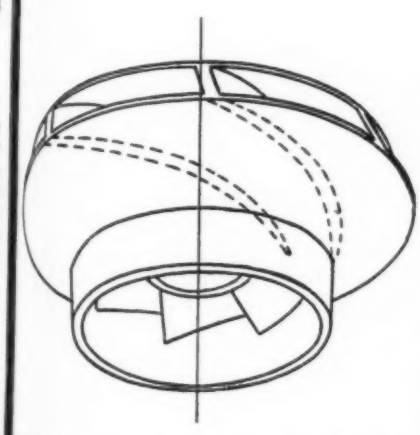


Fig. 10. Design Characteristic of Impeller of Low Specific Speed (Ns)

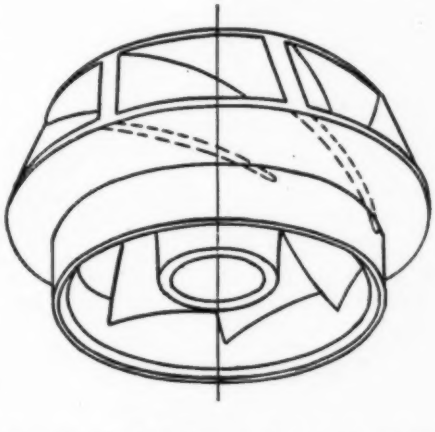


Fig. 11.—Design Characteristic of Impeller of High Specific Speed (Ns)

N_s FOR 1170 R.P.M. DEEP WELL CENTRIFUGAL PUMPS
FOR HEADS FROM 10 TO 40 FEET AND CAPACITIES FROM 50 TO 3000 G.P.M.

HEAD PER STAGE IN FEET

GPM.	10	11	12	13	14	15	16	18	20	22	24	26	28	30	32	34	36	38	40
50	1472	1371																	
60	1612	1503	1406	1322															
70	1741	1623	1517	1428															
80	1862	1735	1622	1527	1445	1373													
90	1974	1840	1721	1619	1533	1456	1388												
100	2081	1940	1814	1707	1616	1535	1463												
110	2183	2036	1905	1790	1696	1610	1534	1405											
120	2280	2125	1989	1870	1770	1682	1602	1468	1356										
130	2373	2212	2069	1946	1842	1750	1667	1527	1411										
140	2463	2295	2146	2020	1912	1816	1730	1585	1465	1363									
150	2549	2376	2221	2091	1979	1880	1791	1641	1516	1411	1322								
175	2753	2566	2399	2258	2137	2030	1935	1772	1637	1525	1429	1346							
200	2944	2745	2565	2414	2285	2171	2068	1895	1750	1630	1527	1439	1358						
225	3122	2909	2720	2560	2424	2302	2194	2009	1857	1729	1620	1527	1441	1361					
250	3291	3031	2867	2699	2554	2427	2312	2118	1957	1822	1709	1609	1519	1442	1370				
275	3451	3217	3007	2831	2679	2546	2425	2222	2053	1911	1791	1688	1593	1513	1442	1375			
300	3605	3360	3141	2957	2798	2659	2533	2320	2146	1996	1870	1763	1664	1580	1506	1436	1377		
325	3752	3497	3269	3077	2913	2767	2637	2415	2232	2077	1947	1835	1731	1645	1568	1495	1439	1377	
350	3896	3629	3392	3193	3023	2872	2736	2506	2316	2156	2020	1904	1797	1707	1627	1552	1488	1429	1377
375	4031	3756	3512	3306	3129	2973	2832	2594	2397	2232	2091	1971	1860	1767	1684	1606	1541	1480	1425
400	4163	3880	3627	3414	3231	3070	2925	2679	2476	2305	2160	2036	1921	1825	1739	1659	1591	1528	1472
450		4115	3847	3621	3427	3256	3102	2842	2626	2444	2290	2159	2038	1936	1845	1760	1687	1621	1561
500			4055	3817	3613	3432	3270	2995	2768	2577	2415	2276	2148	2040	1945	1855	1779	1708	1645
550				4008	3789	3600	3430	3142	2903	2703	2533	2387	2253	2140	2040	1945	1866	1792	1726
600				4181	3958	3760	3582	3281	3032	2823	2645	2493	2353	2235	2130	2032	1949	1871	1803
650					4119	3914	3729	3416	3156	2938	2753	2595	2449	2327	2217	2115	2028	1948	1876
700						4061	3869	3544	3275	3049	2857	2693	2541	2414	2301	2195	2105	2021	1947
750							4005	3669	3390	3156	2957	2787	2631	2499	2382	2272	2179	2092	2015
800							4136	3789	3501	3259	3054	2879	2717	2581	2460	2346	2250	2161	2081
850								3906	3609	3360	3148	2968	2800	2661	2536	2419	2319	2227	2146
900								4019	3714	3457	3240	3054	2882	2738	2609	2488	2387	2292	2208
950									3815	3553	3329	3137	2960	2813	2681	2557	2452	2355	2268
1000									3915	3648	3419	3219	3038	2886	2751	2625	2516	2416	2327
1100									4105	3822	3582	3376	3186	3027	2885	2757	2639	2534	2441
1200										3992	3741	3526	3327	3161	3012	2879	2756	2647	2549
1300										4155	3893	3670	3463	3290	3134	2991	2869	2755	2653
1400											4046	3814	3599	3419	3259	3468	2981	2862	2756
1500											4192	3952	3726	3538	3372	3212	3081	2959	2850
1650												4135	3901	3704	3534	3370	3232	3104	2990
1800													4058	3852	3674	3504	3359	3225	3106
2000														4081	3890	3710	3559	3417	3291
2200															4080	3891	3732	3583	3452
2400																4063	3896	3743	3605
2600																	4057	3896	3752
2800																		4043	3894
3000																		4034	4033
3200																			4043

Table X. N_s Values for 1170 RPM., Head 10 to 40 Ft.

N_s FOR 1170 R.P.M. DEEP WELL CENTRIFUGAL PUMPS
FOR HEADS FROM 45 TO 140 FEET AND CAPACITIES FROM 400 TO 8000 G.P.M.

HEAD PER STAGE IN FEET

G.P.M.	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	140
400	1345																		
450	1427	1320																	
500	1504	1392																	
550	1578	1460	1358																
600	1648	1525	1419																
650	1715	1587	1476	1378															
700	1780	1647	1532	1430	1352														
750	1842	1704	1586	1480	1400														
800	1903	1760	1638	1529	1446	1366													
850	1961	1815	1688	1576	1491	1409													
900	2018	1867	1737	1622	1534	1450	1379												
950	2073	1918	1785	1666	1576	1489	1417	1348											
1000	2128	1968	1832	1709	1617	1528	1454	1384											
1100	2231	2064	1921	1793	1696	1603	1526	1451	1385										
1200	2330	2156	2006	1872	1771	1674	1593	1516	1447	1386									
1300	2425	2244	2088	1949	1843	1742	1657	1578	1506	1443	1388	1333							
1400	2520	2332	2170	2025	1915	1810	1723	1639	1565	1499	1442	1386	1337						
1500	2615	2420	2253	2103	1988	1877	1787	1699	1618	1550	1491	1432	1386	1337					
1650	2733	2529	2353	2196	2077	1963	1868	1778	1692	1620	1564	1502	1450	1402	1360				
1800	2854	2641	2457	2293	2169	2050	1951	1856	1772	1698	1633	1568	1514	1464	1420	1378			
2000	3019	2796	2598	2427	2296	2169	2064	1964	1877	1799	1731	1663	1596	1543	1496	1444	1397	1354	
2200	3188	2951	2746	2566	2428	2294	2184	2079	1987	1906	1834	1763	1694	1638	1589	1538	1490	1444	1360
2400	3358	3107	2893	2706	2561	2420	2305	2195	2099	2014	1938	1864	1794	1736	1685	1634	1584	1536	1448
2600	3529	3264	3041	2847	2695	2547	2427	2312	2212	2123	2043	1966	1895	1835	1782	1731	1679	1629	1537
2800	3698	3421	3189	2988	2830	2675	2550	2430	2326	2233	2149	2069	1997	1935	1880	1828	1775	1724	1627
3000	3865	3577	3336	3128	2965	2804	2674	2550	2441	2345	2257	2175	2101	2037	1980	1926	1872	1820	1719
3200	4030	3731	3482	3269	3100	2934	2800	2672	2558	2458	2367	2283	2207	2141	2082	2026	1971	1917	1813
3500	4282	3963	3699	3473	3294	3119	2978	2844	2724	2619	2524	2436	2356	2287	2225	2167	2110	2053	1945
4000		4335	4043	3797	3604	3414	3262	3117	2988	2874	2771	2675	2589	2514	2447	2384	2324	2264	2148
4500			4375	4108	3900	3696	3534	3376	3240	3117	3007	2906	2815	2737	2667	2601	2538	2475	2352
5000				4405	4184	3966	3793	3625	3482	3352	3235	3128	3032	2950	2877	2809	2744	2679	2556
5500					4455	4224	4041	3863	3712	3576	3453	3342	3241	3155	3079	3008	2941	2875	2750
6000						4469	4277	4090	3933	3791	3662	3546	3441	3352	3273	3199	3130	3062	2935
6500							4501	4305	4144	3996	3862	3741	3633	3541	3460	3384	3314	3246	3117
7000								4508	4339	4187	4049	3924	3814	3720	3637	3560	3489	3420	3290
7500									4521	4364	4222	4094	3982	3887	3803	3725	3653	3583	3451
8000										4527	4381	4251	4137	4040	3955	3876	3803	3732	3599

Table XI. N_s Values for 1170 RPM., Head 45 to 140 Ft.

How "Specific Speed" Is Determined and Ns Values Tabulated for Ready Use

Throughout this article "specific speed" has been mentioned frequently and means for determining this value will now be presented.

The formula used to derive the "specific speed" is expressed as follows:

$$Ns = \frac{\sqrt{GPM} \times RPM}{H^{3/4}}$$

$$\text{or } Ns = \frac{RPM}{\sqrt{H}} \sqrt{\frac{GPM}{\sqrt{H}}}$$

In commercial work, however, it is not desirable to complicate procedure by lavish use of formulas and especially not with mathematical expressions involving odd roots or powers.

Since the value Ns is considered of prime importance (and is, in fact, the crux of this article), values of Ns have been calculated and set up in table form. Two sets of tables are presented for 1,750 rpm. (see Tables VIII and IX) and one for 1,170 rpm. (see Tables X and XI). These cover the two 60 cycle speeds, but a comprehensive set of similar tables could be prepared for various other speeds, and the limits on head and capacity as shown on these representative tables could be extended to any values desired.

The data on sales density, as derived from an analysis of at least 10,000 transactions, indicates that from 70 to 80 per cent of all deep well centrifugal pumps installed in the United States are of the capacity and head per stage covered in these four tables.

By inspection of Tables VIII, IX, X, XI, it will be seen that the head and capacity are graduated in determined values. Specific speed values are determined by finding the capacity in question on the left side of the table and moving across horizontally until the vertical column showing the head in question is reached. In the square in this particular head column on line with the capacity value will be found the specific speed (Ns) for that capacity, head and rpm. under consideration. Specific speeds for conditions not specifically listed can be found by interpolation so long as these are within the limits of the tables.

These tables cover Ns values between a low limit of essentially 1,300 and a high of practically 4,100. This range has been found suitable for deep well pumps of the centrifugal type. Occasionally hydraulic duties are encountered indicating Ns values

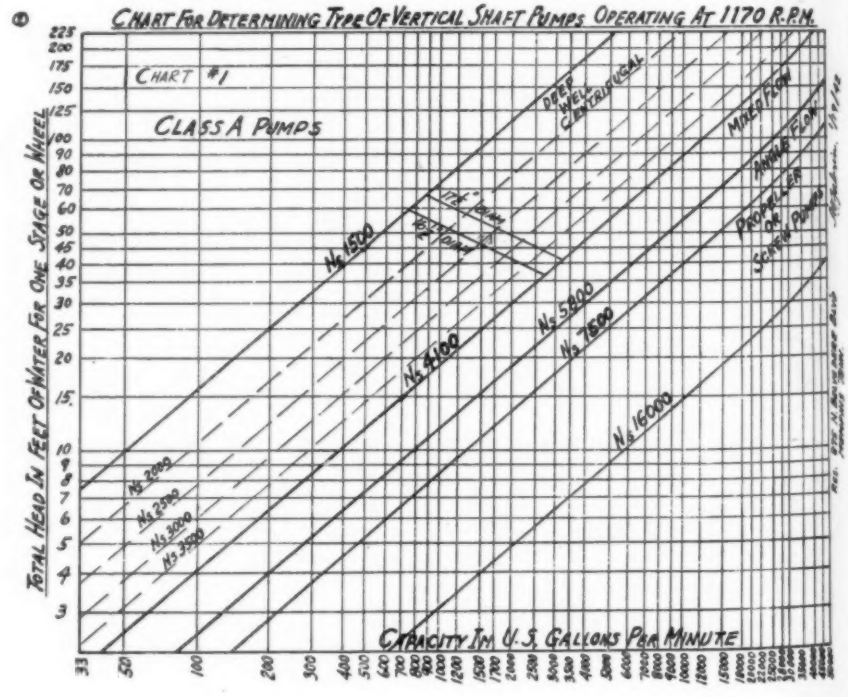


Fig. 12. Chart for Determining Characteristics of Pumps Operating at 1170 RPM.

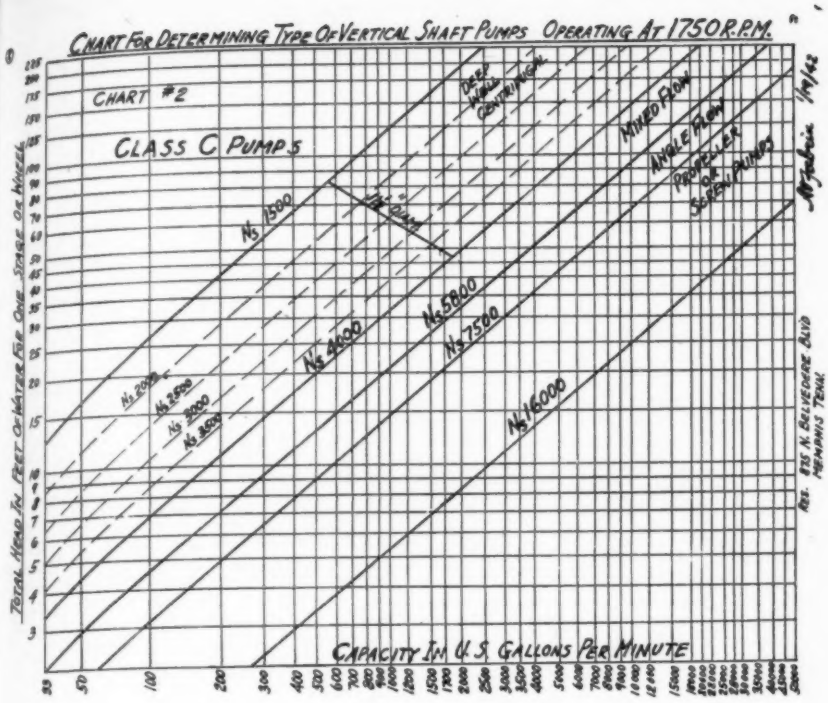


Fig. 13. Chart for Determining Characteristics of Pumps Operating at 1750 RPM

outside these limits. Such cases require pumps of special design and construction.

Analysis Charts for Pumping Problems

The majority of deep well centrifugal pumps problems can be analyzed for suction performance through the use of Fig. 14 when values of Ns and head per stage have been assumed. To illustrate let us consider the permissible suction conditions for two unrelated and independent cases with respect to Ns and head only:

Case No. 1. Ns=2,000 and head is 50 feet per stage. From Fig. 14 it is seen that a pump fulfilling these values will operate when the water level is 20 feet below the bottom impeller without danger of cavitation. (See footnote—Ed.)

Case No. 2. Ns=3,500 and 110 feet per stage. Fig. 14 for this condition indicates that the water level when pumping must stand at least 15 feet above the lowest impeller in order to insure efficient non-cavitation performance.

In a city water works or an industrial installation or any prospective deep well

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[Ed. Note: Cavitation, indicated by sounds like shot passing through the pump casing, has been frequently assumed to be due to small air bubbles traveling under high speed. To the contrary, cavitation is evidence of vacuum within the pump.]

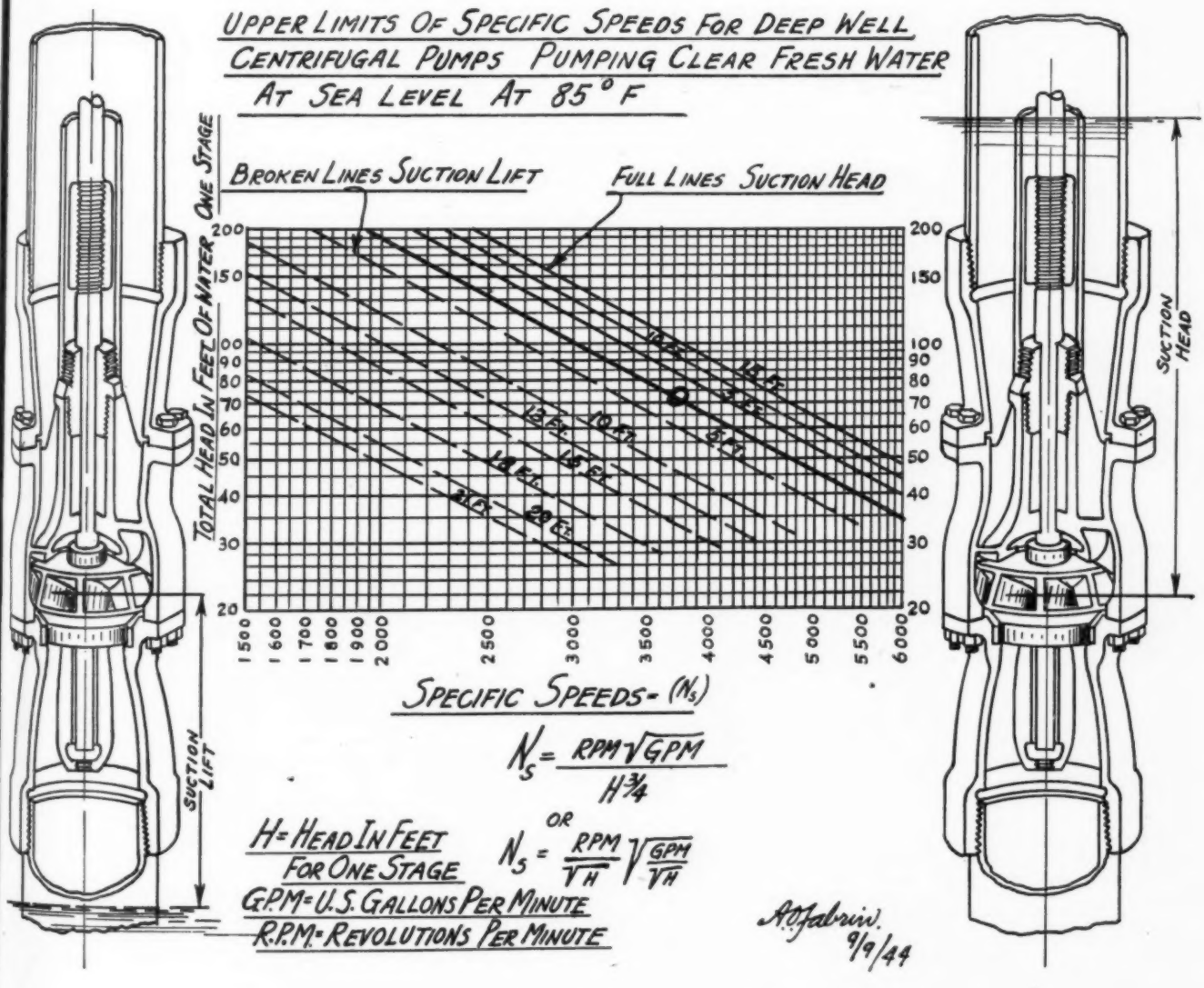

UPPER LIMITS OF SPECIFIC SPEEDS FOR DEEP WELL CENTRIFUGAL PUMPS PUMPING CLEAR FRESH WATER AT SEA LEVEL AT 85° F
BROKEN LINES SUCTION LIFT
FULL LINES SUCTION HEAD
TOTAL HEAD IN FEET OF WATER ONE STAGE
SUCTION HEAD
SUCTION LIFT
SPECIFIC SPEEDS - (Ns)
$N_S = \frac{RPM\sqrt{GPM}}{H^{3/4}}$
OR
$N_S = \frac{RPM}{\sqrt{H}}\sqrt{\frac{GPM}{\sqrt{H}}}$
H = HEAD IN FEET FOR ONE STAGE
G.P.M. = U.S. GALLONS PER MINUTE
R.P.M. = REVOLUTIONS PER MINUTE
A.J. Fabrini 9/9/44

Fig. 14. Upper Limit of Specific Speeds for Deep Well Pumps.

supply, where progressive water level recession is anticipated, pumps with proper characteristics can be obtained that mitigate the annoyance due to inevitable changing well conditions.

Case No. 1 and Case No. 2 were concerned only with Ns and head per stage. Pump selection for favorable suction characteristics can best be shown by a concrete example that confines the choice to two pumps, either one capable of delivering 1,650 gpm. against a head of 250 feet.

Good practice indicates that pumps for this capacity can operate at either 1,170 or 1,750 rpm.

An 1,170 rpm. unit can be termed a Class "A" pump and is preferred because the diameter of this class of pumps insures water passages with smooth flow lines and easy curvature. Five stages can be employed, each stage generating 50 feet. From the specific speed tables the Ns is indicated as 2,510 and this value for 50 feet per stage on Fig. 14 indicates that the pumping water level can recede 18 feet below the bottom impeller before column extension is necessary. The diameter of such a pump is determined from Fig. 12.

A pump of 1,750 rpm. for the hydraulic duty mentioned can be of the Class "C" design wherein the pump proper is held to a relatively small diameter (see Fig. 13). Five stages, each one generating 50 feet head at 1,750 rpm., result in an Ns value of 3,780. From Fig. 14 it is seen that the pumping level can recede to only 8 feet below the lowest impeller before the threshold of cavitation is reached. Any further recession will affect the performance. Assuming that the water level recedes at the rate of 3½ feet per year, it appears that before suction column extension is necessary, the large diameter slow speed pump (1,170 rpm. and Ns 2,510) will operate two years and three months longer than the higher speed (1,750 rpm. and Ns 3,780) small diameter pump.

In some sections the recession rate is greater than 3½ feet per year and naturally the analysis will indicate a different period of operation before column extension becomes necessary. It is realized that if the primary installation is deep enough, the critical period for column extension may be reached at the time when replacements either due to wear or obsolescence are necessary. This is true regardless of type.

Unfortunately many pumps are sold with the major emphasis on first cost, and since a good proportion of cost is in the column, short settings are the rule rather than the exception.

Aside from potential submergence problems, another important feature must be recognized. In quite a few instances the upper well casing or pit, wherein the pump is located, has been impaired by corrosion. An internal liner is often set within the well casing to seal against leakage into the well from undesirable strata. The liner reduces the net diameter of the well pit, forcing the use of a smaller pump. If the primary diameter is small, the use of a liner may necessitate a reduced capacity pump, or mixed flow pump, of high Ns and low head per stage. A great number of stages then become necessary, and such a pump has characteristics different from the centrifugal which may require a motor fitted with an extra high capacity thrust bearing.

Summary

It is believed that if more attention is centered on selecting pumps of preferential diameter, set at favorable depths, deep well pumps will, because of better performance, add to the economic welfare of both the owner and the manufacturer.

PART IV

Charts for Selecting Pumps of Proper Size

ONE of the essential keys to fine engineering achievement is the intelligent use of application data. The real test of engineering lies in performance and when the customer says a machine does a job superlatively well, then something worthwhile has been achieved. The deep well centrifugal pump is one of many machines that depends upon correct application data for successful field performance. Such data differ from the theoretical hypothesis that flourish in academic discussions, in that they are the best fruits of such symposia, applied in laboratory experiments on machines that have been designed according to fundamental laws.

Progressively the machines are modified to incorporate improvements planned to match patterns delineated by reactions obtained in the field of operation. It is the urge to excel in utility and performance that inspires new design and improves the old. When laboratory and field results are reconciled, data are prepared for the use of professional engineers. So delightfully smooth is this process of transition, that it is almost impossible to draw lines of demarcation for each factor as it comes into play.

New fields of operation and changing conditions justify continued research, for it is in the laboratory, when necessity requires, circumstances can be varied at will and conditions artificially created that make it possible to quickly determine improvements that otherwise might require years to materialize. Such a cycle overcomes the rigidity of mistaken opinions that can prevail in the absence of control.

A broad and general view of the activity of these forces in their operations together can be obtained by using a biological analogy. Inferior specimens in the animal kingdom are weeded out, and there remains a group which nature has produced, possessing varying degrees of fitness. The weaker in this group do not survive to reproduce; only the stronger remain to recreate a stronger strain. Progressive generations, while still retaining their basic characteristics, tend to a higher mid-parent, represented by a mean between the varying degrees of excellence in the remaining group.

We can extend the biological analogy into the field of manufacture, and, while this field is intimately connected to that of engineering, it differs in respect that it is not under the direct influence of or subject to the demands of the purchaser. It is twice removed, since engineering must first interpret the sales demand and then plan accordingly. When the designing period ceases, production should begin. Because of the natural and inevitable sequence of steps in manufacture, production lags behind the ideas and expectations of the discriminating purchaser. How much this lag should be, in terms of time, depends upon several factors, such as sales demand, engineering alertness, policy of manufacturer.

Manufacturing policy is perhaps the greatest intangible, as it varies according to the type of machine, and it changes as the development of the object progresses. The modern deep well centrifugal pump has attained its high degree of perfection in less than forty-five years. Like the primary stage of science, which is observational, the many and various designs in the early part of this century were the results of observations on cut and try methods of engineering.

In this period, the accumulation of drawings and patterns has been quite great, and except for the sake of repair service, a large percentage of pump types can be considered obsolete and should be retired from production. Reluctance in retiring machine designs is to a certain extent excusable, if in development, minor changes come so rapidly that supplanting complete old designs would incur financial loss to the manufacturer.

The rate at which designs have improved has been greatly accelerated in the past 20 years, and under the stress of war emergencies, engineering has been more active and creative than ever. This great energizing factor has been dedicated to bringing about complete final victory of war material; the abilities in design and engineering have been planning to use the cumulative results of their experience for the benefit of peacetime enterprise. The manufacturing skills that have been devoted to vital war work will bring to industry the "know how" and "can do" that made possible the quick conversion from peacetime products to precision ordnance. There is no doubt about the beneficial effect all this will have upon future deep well centrifugal pumps.

Consulting engineers, waterworks men, and farmers who depend upon irrigation for crop raising, are naturally interested in improved wells and modern pumps. Generally they know the approximate water supply obtainable from wells in their territory, or can procure such information. Data of this type increase in value as the volume of records swells. The more abundant the files on the subject of water resources, the more complete will be the reflected picture of the natural phenomena which control them.

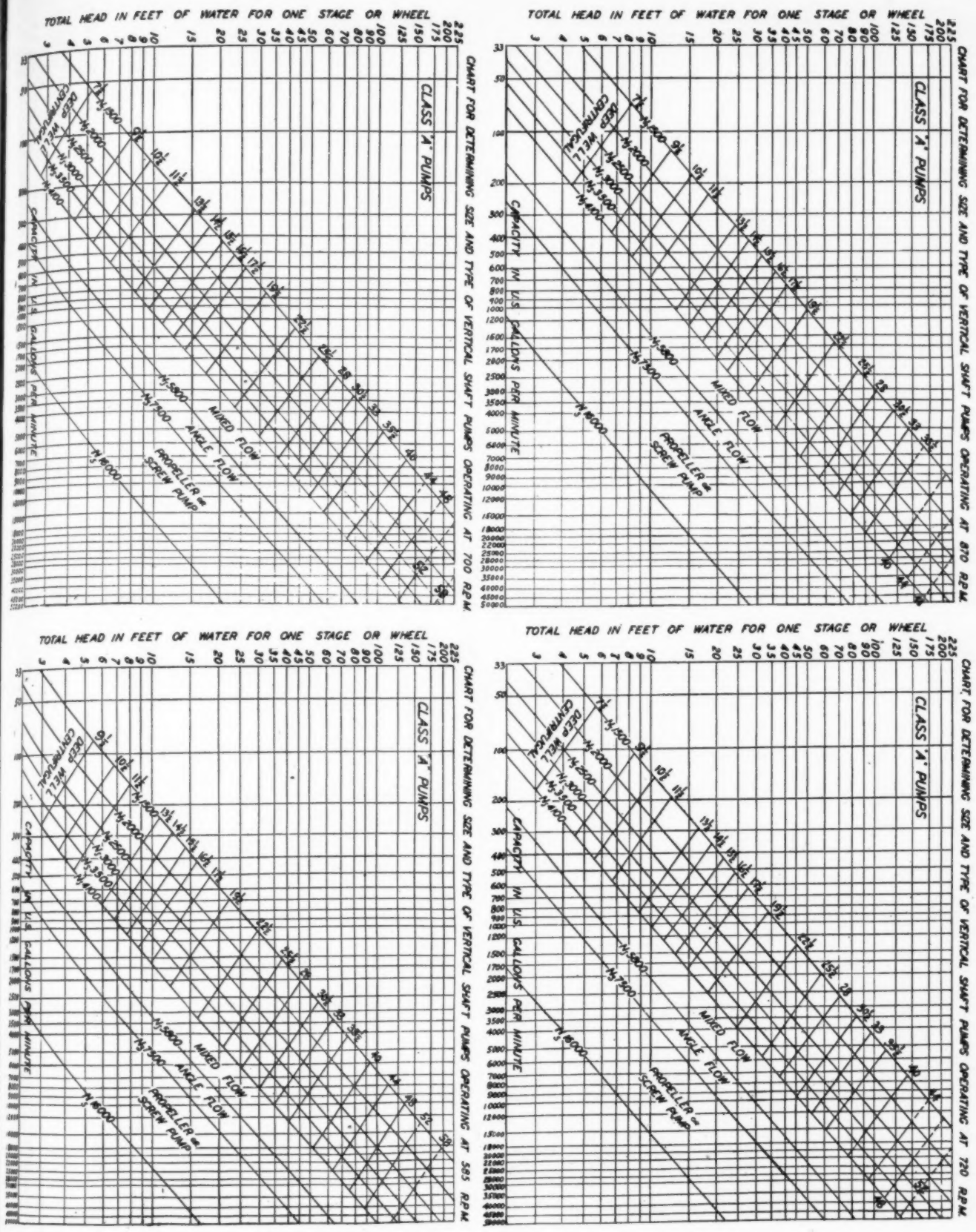
Specific Sizes of Pumps Cannot Be Prescribed for Variable Natural Resources

Since man has no immediate control of these variable natural resources, specific sizes of pump and well cannot be prescribed which for a given capacity would be suitable for all localities. There are some sections in northern Illinois where, due to the action of glaciers, the geology of the earth has been so distorted that a 12-inch well yielding 500 gpm. would be considered excellent. Debris deposited by these glaciers formed what is known as moraines, and the irregularity of these deposits confused the earth strata by indiscriminate distribution of material so that wells in close proximity to each other often vary widely in characteristics.

In other sections of this country the earth strata is composed of alluvial deposits regular in form and depth. Arkansas has territories where the uniformity of the geological structures provides water bearing formations supporting 12-in. wells with productions up to 2,000 gpm. Fortunately, well water for agriculture can be developed in large sections of some of our Western States, where the salubrious climate and the fertile soil invite government action in offering tracts of land for occupation by returned service men.

Charts for Selecting Pumps of Proper Proportions

Selecting pumps of proper proportions for different well yields is important, and since wells must be large enough to accommodate the pumps, it follows that charts embodying data on proper size for certain capacities would be quite useful. Such

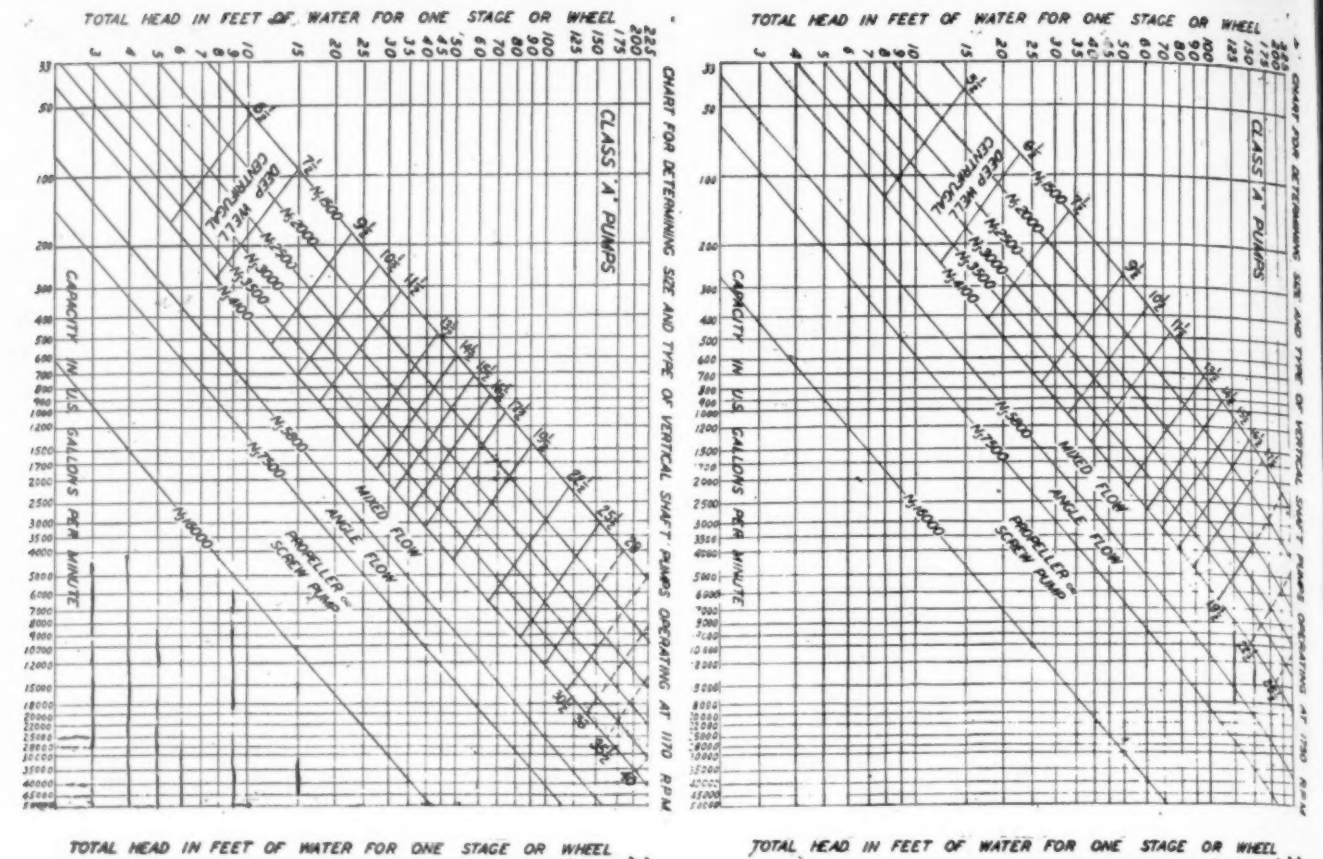

TOTAL HEAD IN FEET OF WATER FOR ONE STAGE OR WHEEL
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 700 R.P.M.
CLASS 'A' PUMPS
CAPACITY IN U.S. GALLONS PER MINUTE
DEEP WELL CENTRIFUGAL
MIXED FLOW
ANGLE FLOW
PROPELLER OR SCREW PUMP
TOTAL HEAD IN FEET OF WATER FOR ONE STAGE OR WHEEL
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 870 R.P.M.
CLASS 'A' PUMPS
CAPACITY IN U.S. GALLONS PER MINUTE
DEEP WELL CENTRIFUGAL
MIXED FLOW
ANGLE FLOW
PROPELLER OR SCREW PUMP
TOTAL HEAD IN FEET OF WATER FOR ONE STAGE OR WHEEL
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 585 R.P.M.
CLASS 'A' PUMPS
CAPACITY IN U.S. GALLONS PER MINUTE
DEEP WELL CENTRIFUGAL
MIXED FLOW
ANGLE FLOW
PROPELLER OR SCREW PUMP
TOTAL HEAD IN FEET OF WATER FOR ONE STAGE OR WHEEL
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 720 R.P.M.
CLASS 'A' PUMPS
CAPACITY IN U.S. GALLONS PER MINUTE
DEEP WELL CENTRIFUGAL
MIXED FLOW
ANGLE FLOW
PROPELLER OR SCREW PUMP

Charts for Determining Size and Type of Vertical Pumps, Operating at Various Speeds

charts are presented herewith and a brief explanation will enable those interested in water supply to use them to the best advantage.

The charts are prepared for deep well centrifugal pumps designated as Class A, which are the most efficient and are larger in diameter than Class C pumps. They are recommended for duties where essentially long periods of operation are required. Such pumps, because of relatively high efficiency, will by reason of power economy justify the cost of a large diameter well.

Class C pumps are less efficient than the A class, as they are of smaller diameter. Since the wells will be smaller, they are also less expensive, and where the duty is intermittent and the operation period during a year is of short duration, the cost of wasted power due to less efficiency than that of Class A will not equal the interest or the extra cost of a well suitable for a large Class A pump.


TOTAL HEAD IN FEET OF WATER FOR ONE STAGE OR WHEEL
CAPACITY IN U.S. GALLONS PER MINUTE
CLASS 'A' PUMPS
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 1170 R.P.M.
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 1750 R.P.M.
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 960 R.P.M.
CHART FOR DETERMINING SIZE AND TYPE OF VERTICAL SHAFT PUMPS OPERATING AT 690 R.P.M.
DEEP WELL CENTRIFUGAL
MIXED FLOW
ANGLE FLOW
PROPELLER or SCREW PUMP

Charts for Determining Size and Type of Vertical Pumps, Operating at Various Speeds

The method of selecting the class of pump with due respect for economy of operation was presented in Parts I and II.

There are two general types of pump applications that require Class A pumps; they are the public utility field and some industries.

Class C pumps are in favor where agricultural irrigation extends over a short period of the year, and they can also be used to good advantage in industries of seasonal activity such as the canning business. In support of the charts which are designed to determine pump sizes, there are presented herewith several instances.

Case No. 1

Required a water supply for a small city located in northeastern Illinois. A survey indicates that the strata of Niagara limestone will, because of faults, fissures and crevices, supply a 12-in. diameter well with a normal capacity of 450 gpm. The electric power characteristics are 60 cycle, 3 phase so a 1750 rpm. motor can be used. With a pumping level of 97-feet and a 75-foot elevated tank, the total head becomes 172-feet.

If the water is discharged direct into the mains, the elevated tank is obviated, but the pump pressure at the surface should be the equivalent of 30 to 35 lb. for domestic services, which is essentially equal to the head from an elevated tank 75-feet high.

From the 1750 rpm. chart, it can be seen that the pump can be either a 11½-in. in diameter Class "A" unit of 3 stages with an Ns of 1800, or 9½-in. diameter Class "A" pump, 5 stages, with an Ns of 3000.

If steel casing is not used, as is often the practice in rock well construction, there may be protrusions encroaching on the normal diameter that make it difficult, if not impossible, to install the 11½-in. diameter pump. The choice reverts to the 9½-in. pump, which because of the higher Ns, will be slightly better in efficiency.

Case No. 2

Two hundred seventy-five acres of rice to be irrigated using a pumping rate of 1800 gpm. for 75 days, operating 24 hours a day. In Northeastern Arkansas rice fields procure their irrigation water from alluvial strata that makes possible wells of 12-in. diameter for 1800 gpm. It is, of course, recommended that, where conditions permit, the well casing should be larger than 12 in. With the pumping level 48-feet and discharge at the surface direct into the irrigation header requiring no head above ground, the total head and pumping level is the same.

Referring to the 1750 rpm. chart, it is seen that a pump 12¾ in. will be suitable. This is a Class A unit, but since the duty of the pumping plant is intermittent and the period of operation relatively short, a Class C pump is satisfactory. The diameter of Class C pumps is generally 90 per cent of the A Class, so accordingly, the pump in our problem will become 11½ in. in diameter. Further reference to the chart indicates a single stage pump will meet the hydraulic conditions.

When using these charts, it must be borne in mind that deep well centrifugal pump manufacturers have standardized on certain sizes and if interpolated values from the charts denote diameters falling between two standard values, use the size nearest the interpolated point.

It is realized that there are conditions where, because of the graduation of pump sizes, the choice of pump class is optional. This is especially true when the choice is confined to one speed.

Where the nominal pump size exceeds 14½ in., there may be circumstances where a municipal pump problem reverts to a choice between a high and low speed pump. Because of the low first cost, there may be a temptation to use a high speed Class C pump instead of a low speed Class A. If a complete analysis is made according to the outline in Parts I and II, it can be shown that false economy may obtain if operating expense is not given full consideration.

If the problem of size determination is approached from an engineering point of view, and action is in accord with good engineering judgment, it is certain that the dependent financial result will be favorable with a Class A pump.

Reflecting on these remarks and considering the examples, Case No. 1 and Case No. 2, it will be observed that the charts do not predicate arbitrary procedure or prescribe inflexible values. These charts show finite pump diameters for various capacities, and heads per stage when the revolutions per minute are shown. There are eight (8) charts, covering eight (8) different motor speeds, ranging from a high speed of 1750 to a low of 585 rpm. This will take care of the majority of deep well centrifugal pump problems using 60, 50 or 25 cycle motors.

While precise dimensions are indicated, certain tolerances are acceptable. The charts pertain to a collection of pumps, all of homologous design, but by slightly modifying the impeller vanes at the periphery, the head can be increased at least 10 per cent for any size, and in some instances more. If, after taking advantage of the 10 per cent margin, the choice falls between two standard sizes, use the larger.

The addition of one or two blades in an impeller will boost the total head per stage more than 10 per cent, but often this results in a pump with a pressure volume characteristic a little too flat for good well operation. Parts I, II and III concern the selection of the proper class pumps with respect for economy.

SOLUTION FEED CONTROL

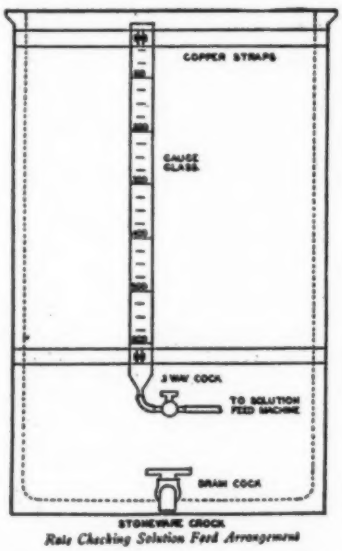
By T. M. RIDDICK

Consulting Chemist, New York City

WITHIN the past few years there has been a rapid increase in the use of solution feed equipment for pressure filters, and small water supplies with pumping rates of less than about 700 GPM. This trend now fills the long-felt need for apparatus of a capacity below that of standard dry feed machines or vacuum-type chlorinators. These feeders are of diaphragm or piston type and discharge roughly a maximum of 250 ml. per minute for single units, with duplex rating of approximately twice this figure. Experience with both plunger and diaphragm pumps, operating under a negative head, emphasizes the possibility of flow stoppage due to clogging of suction or discharge lines, loss of prime through air leakage, air binding, etc. If the machine is fed by a suction hose extending over the rim of the solution crock it is most inconvenient and difficult to judge at what rate the solution is being added, and whether the discharge is constant.

A new type of solution feed arrangement is shown in the accompanying drawing. It has been used with excellent success by the writer.

The crock illustrated is a fifty-five gallon stoneware pot of substantial construction. The draincock can be furnished as standard equipment and provides an easy way of drawing off sludge which will in time accumulate from commercial chemicals. Six inches above the center line of the draincock is placed a three-eighth inch three-way hard rubber cock and T. (See sketch.) This location prevents clogging of the feed line by sludge or chemicals which have not completely dissolved. (It is better to have this cock installed at the factory, since the hole may be drilled more readily at the shop than in the field.)



Rate Checking Solution Feed Arrangement

The gauge glass is made by drawing down one end of heavy-walled Pyrex tubing of 38 mm. diameter. The tube, as pictured, is calibrated at 25 ml. and number marked at 100 ml. intervals. However, it may be graduated at intervals of 10 ml. with no overcrowding of division lines. The gauge glass enables the operator to observe the height of solution in the crock without close inspection, and also affords a means for measuring the amount of solution used daily since the tube calibration may be interpreted in terms of gallons of crock capacity, or pounds of chlorine, alum, ferric-chloride, etc.

In order to ascertain the specific rate of feed, it is only necessary to turn the threeway cock 180 degrees. This causes the solution to be drawn from the gauge glass instead of from the crock, and by noting the time (in seconds) required for a drawdown of say 100 ml., or, by observing the drawndown in ml. for a period of one minute, the rate of discharge of the feed machine can be accurately established.

It also serves as a very ready method for determining whether or not the machine is feeding at all. For instance, clogging of the feed line often occurs when using chemicals shipped in burlap bags, due to small threads which pass into the crock when bags are emptied.

The gauge glass is held in place by two copper or monel straps, which secure it to the solution pot.

It is advisable to attach a high speed mixer to the crock to assist the operator to quickly and easily prepare solutions. When hypochlorites or ferric salts are used the shaft and propeller of the mixer should be coated with rubber or heavy bituminous enamel.

The cost of the equipment is negligible when considering the operating facilities afforded.

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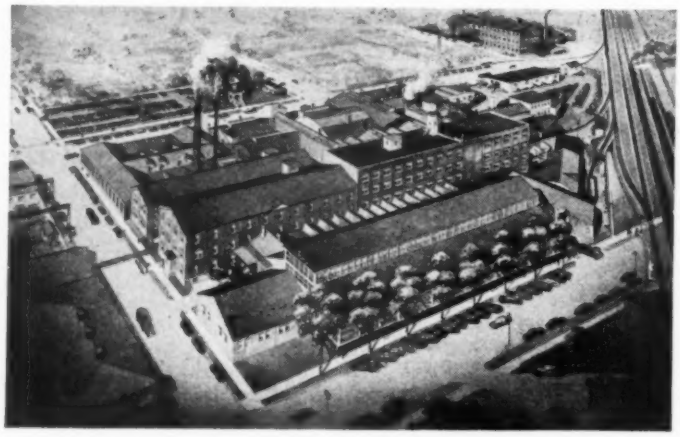
DEEP WELL PUMPS
DIAPHRAGM PUMPS
DRAINAGE PUMPS
PORTABLE PUMPS



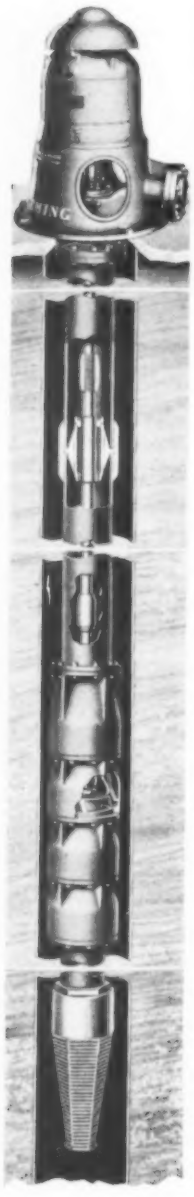
Group of Factory Buildings of The Deming Company, Salem, Ohio.

DEMING PUMPS
FOR WATER WORKS AND SEWERAGE

(Following listings appear in "Classified Index of Products" in this publication).

ROTARY PUMPS
SELF PRIMING PUMPS
SEWAGE PUMPS
SLUDGE PUMPS
SUCTION AND FORCE PUMPS
SUMP PUMPS
TURBINE PUMPS

Deep Well Turbine Pumps



These *water lubricated* deep well turbine pumps are designed to deliver capacities ranging from 15 to 3,000 gallons per hour and are widely used for municipal water supply, drainage, irrigation, swimming pools, etc.

The multi-stage vertical centrifugal pump construction allows the pumping unit to be placed at any depth from the surface, preferably submerged at all times.

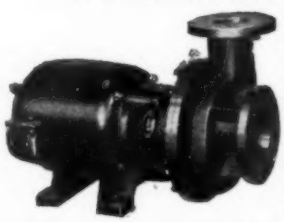
Vertical hollow-shaft motors are standard construction although other types of heads can be supplied such as belted drive heads, gear increaser heads, steam turbine heads, flexible coupling, or combination type heads.

Features of Deming Deep Well Turbine Pumps include semi-open, adjustable type impellers held in place with split tapered compression sleeves; Goodrich cutless rubber bearings of the fluted type are used in each bowl, or stage, and at a maximum interval of 10 feet in the column pipe. These bearings are thoroughly flooded and lubricated by the water being pumped. Stuffing box in the discharge head can be easily adjusted or repacked from ground level.

For complete information on Deming Deep Well Turbine Pumps, write for BULLETIN 4700-8.

Centrifugal Pumps

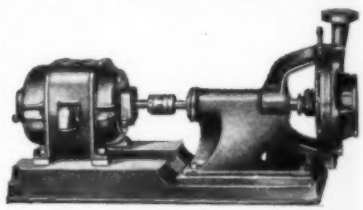
"MOTOR MOUNT" CENTRIFUGAL PUMPS



Compact, dependable units, Deming "MOTOR MOUNT" Pumps combine high efficiency and simplicity at moderate cost. There are 63 units in the line. Capacities range from 5 to 650 gallons per minute against heads from 10 to 85 feet. Features include semi-enclosed, three-vane impeller with non-overload characteristics; adjustable for capacity, head, clearance and wear. Motor is drip proof type with moisture resisting insulation. Deep groove, over-size ball bearings. Fan ventilation.

Complete data in BULLETIN 4302. Write for copy

SIDE SUCTION CENTRIFUGAL PUMPS



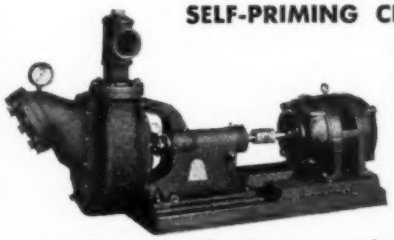
Standardized in design, Deming Side Suction Ball Bearing Centrifugal Pumps eliminate the need for expensive specially designed equipment for a wide scope of pumping requirements.

There are 21 pumps in the line. Sizes range from 1 to 10 inches. Capacities range from 10 to 3,600 gallons per minute against heads up to 260 feet.

Deming Side Suction Centrifugal Pumps can be furnished for belt drive, electric motor, or gasoline engine drive.

Complete data in BULLETIN 4200. Write for copy

SELF-PRIMING CENTRIFUGAL PUMPS



These electric motor-driven units are designed for sump pump service with float switch control. Also used for cleansing swimming pools, core sucking service in ice plants, etc. Priming operations completely automatic. Semi-enclosed, non-clogging impeller.

Pumps can be furnished direct connected through flexible couplings; or to electric motors; or gasoline engines; or with pulley for belt drive.

Capacities range from 600 to 18,000 gallons per hour.

Complete data in BULLETIN 3000. Write for copy

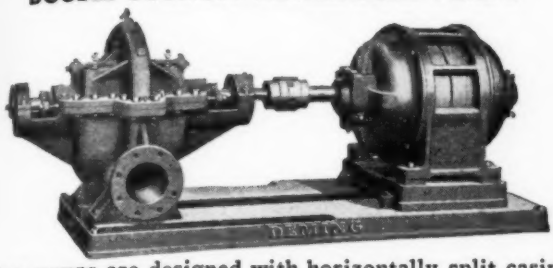
THE DEMING COMPANY

ESTABLISHED 1880

SALEM, OHIO, U. S. A.

Centrifugal Pumps

DOUBLE SUCTION CENTRIFUGAL PUMPS



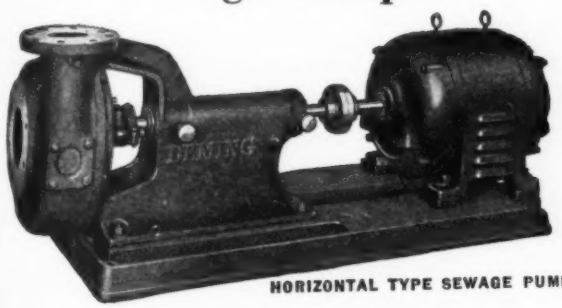
These pumps are designed with horizontally split casing. All features conform to latest engineering practice to obtain maximum efficiency for this type of unit. Recommended for working pressures up to 200 pounds.

Heavy ball bearings at each end of shaft take all lateral and end thrust. Rotating elements are in perfect static and dynamic balance, assuring a vibrationless pump at all speeds.

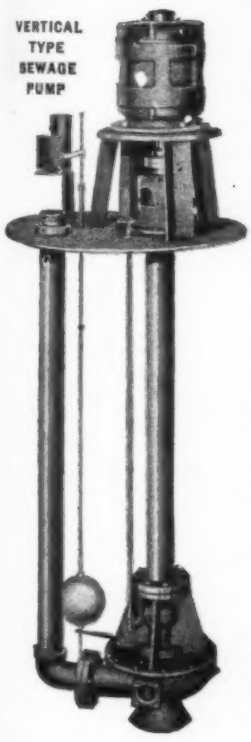
The line includes a wide range of sizes from 1½ to 10 inches with capacities up to 5,000 gallons per minute against heads up to 350 feet.

Complete data in BULLETIN 5003. Write for copy

Sewage Pumps



HORIZONTAL TYPE SEWAGE PUMP



VERTICAL TYPE SEWAGE PUMP

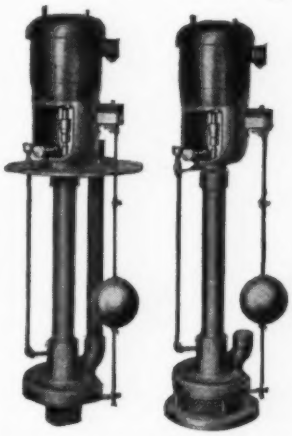
Deming non-clogging horizontal and vertical type sewage pumps are designed to handle safely and efficiently raw, unscreened sewage, storm water disposal, drainage, or other pumping requirements where liquids carrying along refuse, dirt, silt, rags, sticks, and stones must be handled with minimum danger from clogging, breakage, or undue wear.

These pumps are used in Sewage Disposal Plants, Paper Mills, Quarries, etc., and are suitable for many applications where standard Centrifugal Pumps are not designed for the indicated requirements.

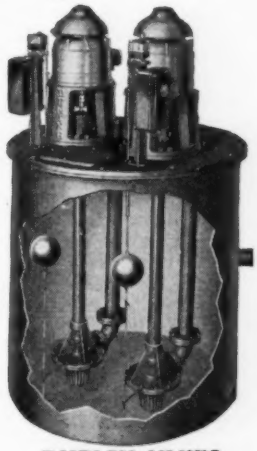
Deming Sewage Pumps are built in horizontal and vertical types for capacities from 60 to 1,200 gallons per minute and for heads not to exceed 80 feet.

As these pumps usually require individual engineering, a complete statement of conditions should accompany each inquiry.

Sump Pumps



SUMP PUMPS



DUPLEX UNITS

Deming Sump Pumps are designed in various types in a wide range of capacities from 10 to 3,200 gallons per minute with heads up to 120 feet and speeds from 860 to 1,750 r.p.m. for motor drive.

Construction of Deming Sump Pumps offers many important features including: (1) Impeller adjustable for capacity, head and wear; (2) Impeller fitted to shaft with taper, key and nut; (3) Full weight column pipe with precision thread; (4) Double length bottom shaft bearing with large grease chamber.

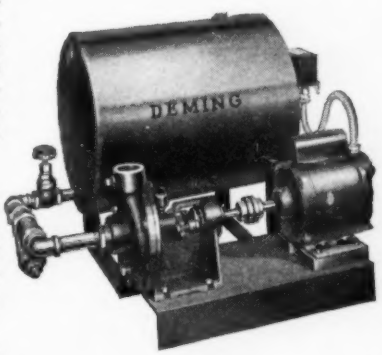
Deming Sump Pumps are furnished either in SINGLE or DUPLEX units of either wet or dry pit type. Can be installed in pits of every description wherever water collects and has to be emptied into sewer lines at a higher level or delivered above ground.

Duplex units meet requirements where extra precautions must be taken to insure uninterrupted service.

The complete line of Deming Sump Pumps is illustrated and described in detail in BULLETIN 4605. Write for copy

Condensation Return Units

Deming pump and receiver units are designed to return, automatically, to boilers the hot water of condensation from radiators, coils, and steam operated machinery.



Condensate is automatically returned to the boiler by the pump, operation of which is controlled by an enclosed float switch.

Units are equipped with horizontal reciprocating pumps or side suction centrifugal pumps, depending upon capacity, pressure, and most efficient operation.

Receiver tanks are of extra heavy welded boiler plate. Tanks furnished with water gauge glass and with petcock and check valve in top, as illustrated.

Motors are furnished single phase, 2 or 3 phase, or direct current as specified. All units are equipped with motor protective device and are completely assembled and wired.

WATER HAMMER CORRECTIVES

By RICHARD BENNETT, Hydraulic Engineer
City Engineer's Office, Phoenix, Arizona

PIPE LINES subjected to sudden shock or recurring vibration due to water hammer, become weakened and operate inefficiently. This destructive nuisance may also pull pipe hangers loose or create damaging leaks.

Destructive water hammer may actually be present in water lines even where its presence is not indicated by violent hammering and noisy vibration. For the most part this fact is not generally realized or recognized.

Cause of Water Hammer

If flow in a pipe is suddenly stopped, the energy built up by the flowing water produces a high pressure which may result in a terrific impact. This is caused by the non-compressible liquid (water) rebounding in the supply lines. This rebound impact is due to the sudden stopping of water flow every time a faucet or valve is closed. Power for operating hydraulic rams, which force water many times higher than the static head on the power water supply line, is thus generated by intermittent quick closures of valves attached to the ram.

In order to have conception of this force in small pipe, when water hammer occurs the pressure is increased by about 60 pounds per square inch above the flow pressure for each foot per second of sudden decrease of velocity of flow. This means that if a flow velocity of 10 feet per second is stopped instantly, a maximum water hammer pressure rise of (10x60) 600 lbs. per square inch may occur. This pressure is added to the normal static pressure at the point of impact.

Destructive water hammer must be eliminated to avoid the nerve-racking noise from which the term is derived; to reduce stress in the pipes; to safeguard plumbing fixtures; to avoid costly leaks and repairs; and to prevent operating delays.

Correctives

Relief from destructive water hammer may be accomplished by relief valves, but these can be used only in special cases. Relief can be obtained by air chambers, but the difficulty of keeping air in the chamber makes this method impractical under many conditions of operation. In many instances positive and permanent relief can be obtained by the installation of surge suppressors. These are sometimes given trade names such as shock absorber, water hammer arresters, etc. Just as the automobile shock absorber absorbs the bumps of the highway, so does a good surge suppressor cushion the terrific impact of water rebounding in the piping system.

Unless a surge suppressor is installed, the water backs up with terrific force and continues to bound and rebound in the pipe lines every time the flow of water is suddenly checked. With a good surge suppressor this pounding and hammering is overcome by absorbing and dispelling the shocks, and strain in the pipe is relieved.

In selecting a surge suppressor it is desirable that it afford protection from water hammer under all conditions of service; that it be easy to install; require no periodic adjustments; require little or no maintenance; that it operate in any position; that it be unaffected by hot water; and that it be reasonably priced.

Under some conditions it is possible to determine in advance the behavior of the surge suppressor, and a method for calculating the degree of relief from water hammer pressure for a given piping layout is obtained by the relation between useful volume of air in the surge suppressor for the various rates of discharge through the pipe line.

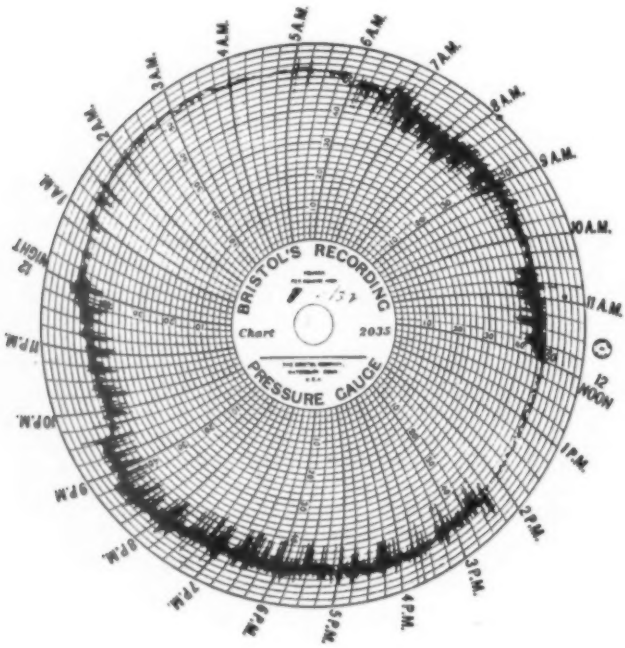
Theoretical considerations are generally to assume the discharge suddenly stopped by valve closure. This seldom occurs in actual practice. The size of the surge suppressor to be selected for each installation should be adequate to reduce the maximum water hammer pressure that can be caused by quick closure of any one valve or faucet.

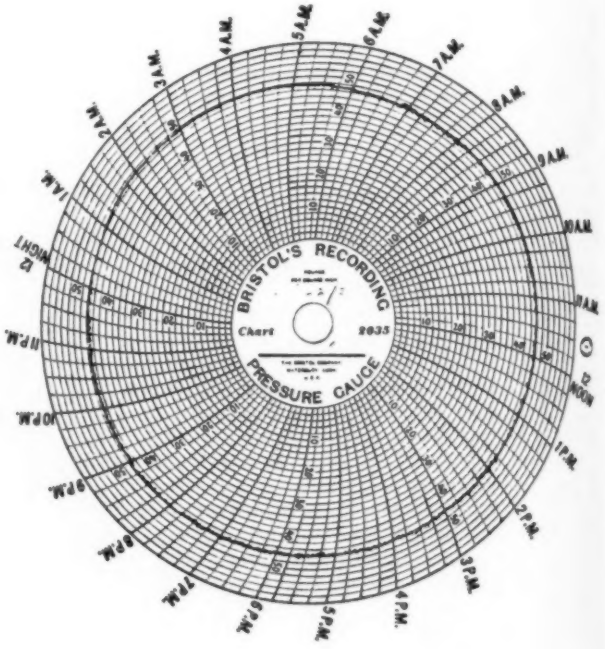
In Fig. 1 is illustrated the action of water hammer as recorded on a time-pressure diagram showing the incessant impact shocks and pressure fluctuations. The system is free of this shock effect (even though hammering may not be heard) only during those hours when no water is being drawn.

When an efficient surge suppressor is installed the time-pressure chart recording should look something like the chart shown in Fig. 2. A proper suppressor will quiet the water hammer by dissipating impact shocks and overcoming the pressure fluctuations

Surge Suppression Devices

Perhaps you have come to the conclusion of "Why not eliminate the source of the water hammer?" Quick closing valves are the cause of most of this trouble, but modern equipment of the present





A Story Told by Two Record Charts

Fig. 1—Reveals the incessant impact shocks and fluctuating pressures when water hammer is present.

Fig. 2—After the installation of a good surge suppressor the record chart should look something like this.

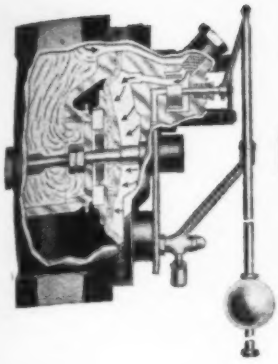


Fig. 3—The Clayton Valve—Closed Position
Is a quick closing valve designed to preclude hammer by uniform and governed rate of closure.

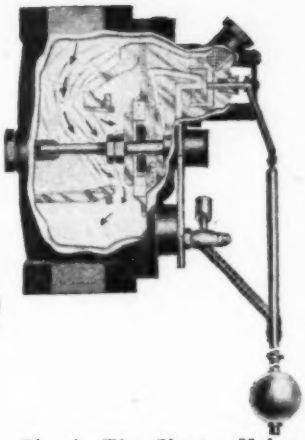


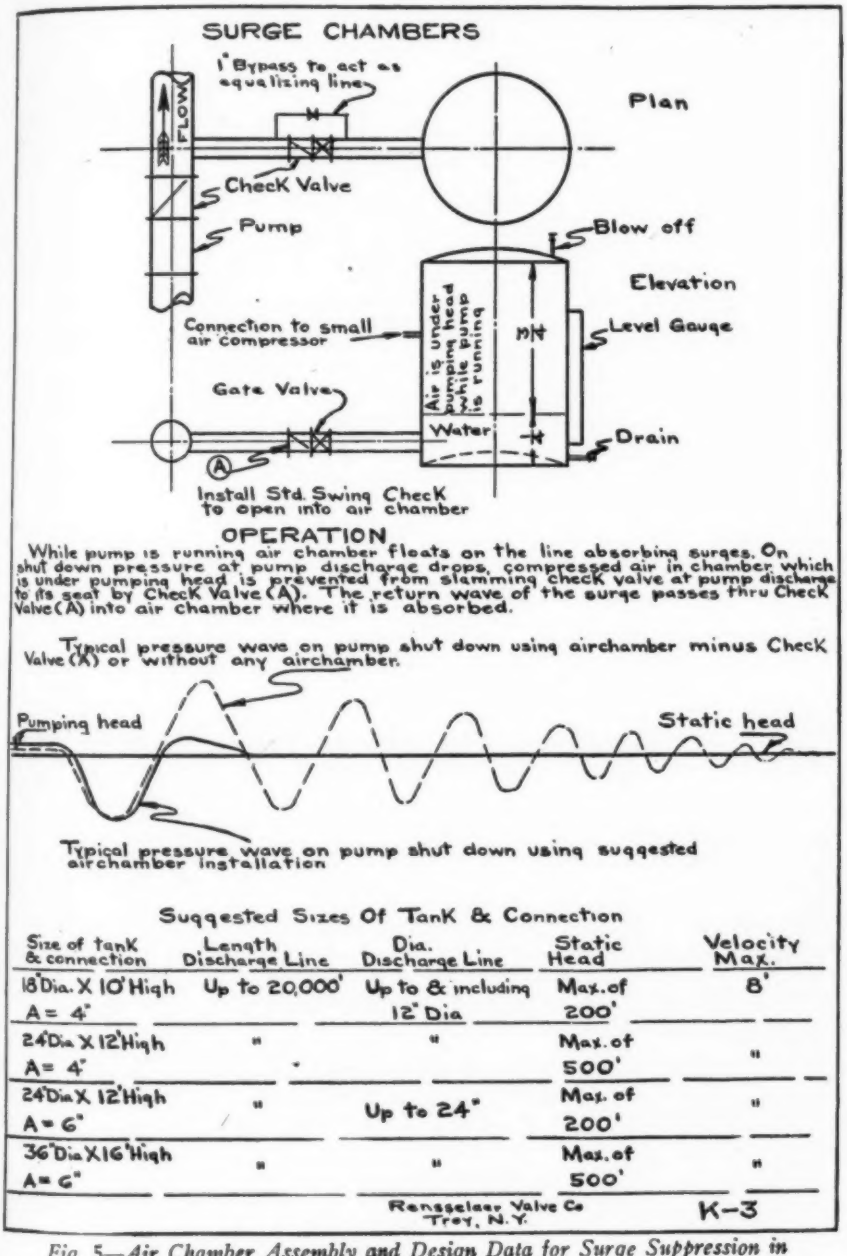
Fig. 4—The Clayton Valve—Open Position.
Always wide open or fully closed, functions well in rapid fillings of vats, tanks, etc.

day increasingly requires quick closing valves and water customers insist on quick closing faucets and fixtures, therefore water hammer troubles may be expected to increase, rather than decrease, in the future in most water works.

Valve manufacturers, as a group, have done very little to produce equipment to meet this situation, however, the Clayton valve has been designed for this purpose. It can be adapted to almost any type of flow control problem. Figs. 3 and 4 show this valve in the closed and open position. The arrows show that the valve is kept closed by water pressure on the back of the diaphragm. This valve can be furnished with an adjustable needle control for regulating the closing speed to meet any given condition. The illustrations show float control for rapid tank filling and smart shut off, but the manufacturer states that it can be adapted to remote, automatic, manual, elecric, or any type of control desired. Fig. 4 shows that when pressure behind the disc is removed the line pressure forces the diaphragm assembly away from the seat. This valve is always wide open or fully closed, and closes at a governed uniform rate to eliminate line shock when the shut-off occurs.

Relief Valves

Relief valves are sometimes used to eliminate water hammer but they can be used only in special cases, due largely to the spill of water which must be cared for, and do not operate except under


SURGE CHAMBERS
1" Bypass to act as equalizing line
FLOW
Plan
Check Valve
Pump
Blow off
Elevation
Connection to small air compressor
Air is under pumping head while pump is running
Level Gauge
Gate Valve
Water
Drain
A
Install Std. Swing Check to open into air chamber
OPERATION
While pump is running air chamber floats on the line absorbing surges. On shut down pressure at pump discharge drops, compressed air in chamber which is under pumping head is prevented from slamming check valve at pump discharge to its seat by Check Valve (A). The return wave of the surge passes thru Check Valve (A) into air chamber where it is absorbed.
Typical pressure wave on pump shut down using airchamber minus Check Valve (A) or without any airchamber.
Pumping head
Static head
Typical pressure wave on pump shut down using suggested airchamber installation
Suggested Sizes Of Tank & Connection

Size of tank & connection	Length Discharge Line	Dia. Discharge Line	Static Head	Velocity Max.
18" Dia. X 10' High A = 4"	Up to 20,000'	Up to & including 12" Dia	Max. of 200'	8'
24" Dia X 12' High A = 4"	"	"	Max. of 500'	"
24" Dia X 12' High A = 6"	"	Up to 24"	Max. of 200'	"
36" Dia X 16' High A = 6"	"	"	Max. of 500'	"

Rensselaer Valve Co. Troy, N.Y. K-3

Fig. 5—Air Chamber Assembly and Design Data for Surge Suppression in Centrifugal Pump Operation.
Courtesy Rensselaer Valve Co.

Fig. 6—"Wacor" Water Hammer Arrester
Position of bellows compression unit at time of normal pressure.

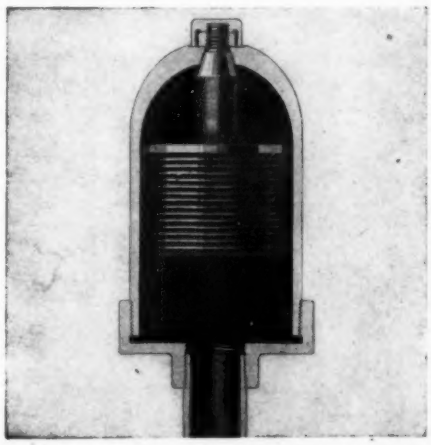


Fig. 7—"Wacor" Water Hammer Arrester
Position of bellows compression unit when absorbing hammer shock.

Fig. 8—The Josam Shock Absorber
Phantom view showing four coil springs in dry side of diaphragm chamber, which absorbs and dissipates the shock.

high surge pressure. However, many have secured satisfactory results from these devices at pumping stations and hydro-electric plants where water spill is not a problem.

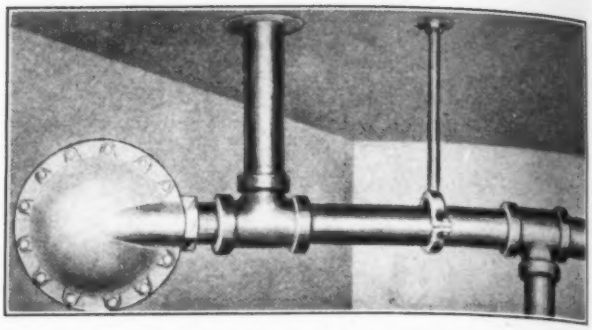


Fig. 9—A Josam Shock Absorber
(Installed at typical location point on the end of a long straight run of pipe.)

Air Chambers

Relief from destructive water hammer may be accomplished by air chambers, but the difficulty of keeping air in the chamber makes the air chamber impractical, unless given close attention, or air recharging can be automatically done with compressors.

Fig. 5 illustrates an air chamber assembly. When the pump is running the chamber of compressible air floats on the line absorbing or cushioning surges. When a pump shuts down pressure at the discharge drops instantaneously and then the back surge follows. Compressed air in the tank, which is under pumping

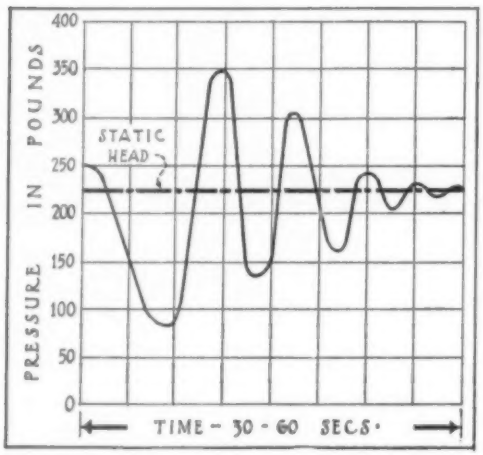


Fig. 11—The Effects of a Slow Closing Check
The lag in closing is responsible for the marked surge and hammer pressure.

Fig. 12—The Effects of a Quick Closing Check
Showing the results of rapid closure when effectively timed ahead of the first rebound of the water column.

Fig. 10—Illustrating Other Typical Location Points for Shock Absorbers and Hammer Arresters

Fig. 13—The Smolensky Check
A wholly mechanical valve

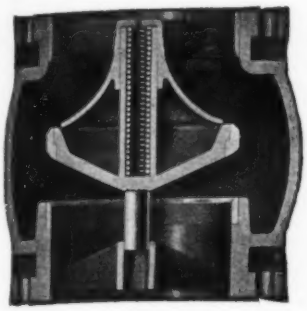


Fig. 14—Interior of the Smolensky Check
Spring force enables this valve to close slightly in advance of cessation of flow away from the stopped pump.

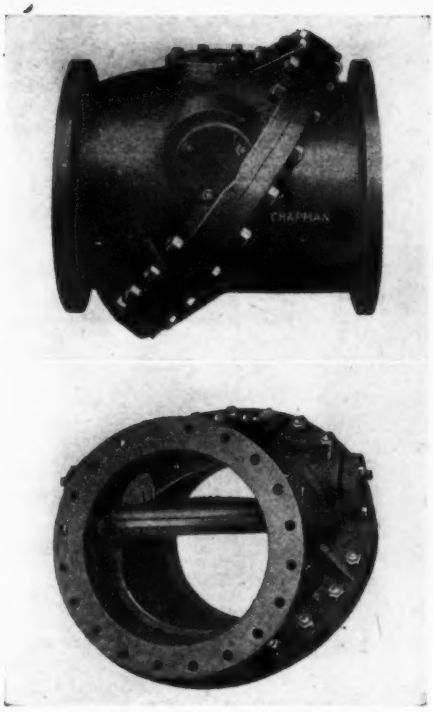


Fig. 16—Chapman's "Non-Slam" Check
Features the streamlined tilting disc, closing gradually to completion at instant of flow cessation away from pump.

head, is prevented from slamming the check valve on the pump discharge line to its seat by the functioning of check valve (A). The return wave of the surge, however, can pass through the check valve (A) into the air chambers where it is markedly cushioned and gradually absorbed during gradually diminishing surges.

For most all cases of water hammer, of the type caused by quick closing valves on all but the largest lines, a surge suppressor which may be attached to the pipes and operate automatically without maintenance is to be preferred. Of this type the "Wacor," shown in Figs. 6 and 7 is very reliable. This suppressor has been thoroughly engineered for small piping systems, the manufacturer having financed an extended research program in the hydraulic laboratories of the University of Wisconsin, where all possibilities of this equipment were rather thoroughly explored.

"Wacor" Water Hammer Arrester is manufactured in a number of sizes for pipe lines up to 10-inch in diameter. It is a combination mechanical-pneumatic type of absorber constructed with a closed metal bellows or compression compartment. The latter is filled with a special compressible emulsion so that air can neither escape nor be absorbed by the water. It is particularly adapted to all ordinary house services where water hammer exists or where high pressures engendered by rapid valve closure are damaging piping and fixtues.

When this suppressor is put on the line the sealed (compression chamber or bellows (containing the emulsion) is slightly compressed as the water pressure is turned on the system. This is shown in Fig. 6, with the bellows at resting position. If now a valve or faucet is opened and water flows through the pipe, the bellows expands somewhat due to the reduction of the pressure at its base. As the valve or faucet is closed the velocity of the water in the pipe line is reduced, resulting in an increase of pressure. This compresses the bellows, resulting in an increase of pressure on the emulsion sealed within the bellows. The pressure inside and outside of the bellows thus becomes equalized. Work done in compressing the fluid emulsion within the bellows is responsible for the absorption or damping of the hammer pressure in the pipe line to which the arrester is connected. This is shown in Fig. 7, and illustrates the position of the bellows, when absorbing the hammer shock.

This type obviates the need for the attention which air chambers require. They are used with quick action valves and high velocities of flow, and can be used where water hammer pressure originates in the municipal distribution system and affects the consumers' service line or plumbing installation.

Another surge suppressor for small piping systems is the Josam Shock Absorber, which is shown in Fig. 8. It operates on the diaphragm principle and is very efficient when properly sized to the individual problem. This suppressor absorbs shock by compression of four coil springs very much after the manner of the coil springs known as Knees in modern automobiles. The diaphragm moves out against these springs located on the dry side of the unit.

Location of Suppressors

Practice varies widely as to the proper installation point for surge suppressors; some will place a suppressor at the end of all long runs of pipe; others install at the end of a battery of fixtures, but it seems agreed that it should be placed *as near to the valve causing the water hammer as is permissible.*

It is desirable to place the suppressor so that the opening is at the bottom if possible. This will avoid hazards from sediment being washed into the casing. Wherever a greater capacity is required to reduce water hammer pressure than can be furnished by a single suppressor, any number can be placed in the pipe line, either in scattered positions or together at one fitting.

Figs. 9 and 10 show typical installation points for suppressors of this general type.

Water Hammer with Centrifugal Pumps

The use of centrifugal pumps presents a major problem in the control of surge water and minimizing of water hammer. When the power is shut off the water in the discharge line reverses its direction of flow and if not controlled will cause reversal of pump and motor.

The installation of the flap type check valve with centrifugal pumps increases the effect of surge waves and water hammer, if not actually being responsible for such. Ordinary check swing valves, due to slamming, cause abnormal disturbances in the pipe lines. Slam leads to serious trouble because of the resulting vibration of pipe lines and adjacent structures, opening up the pipe

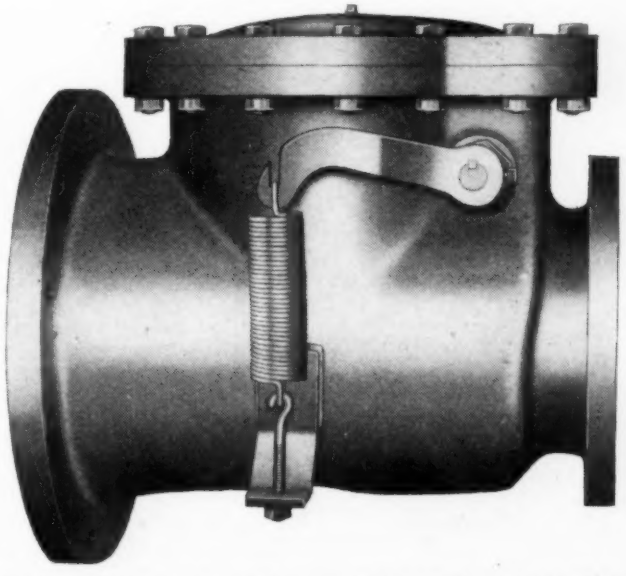
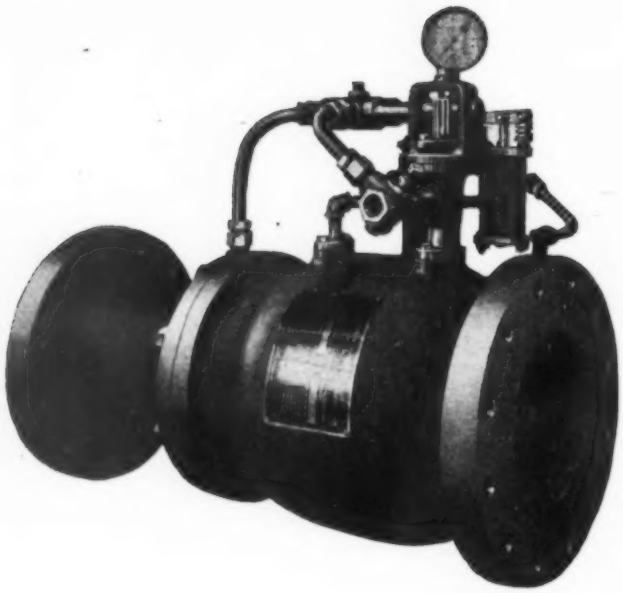
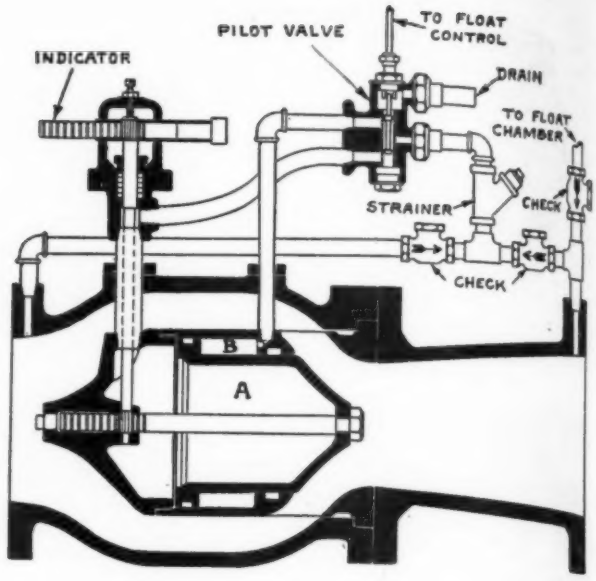


Fig. 15—The Rensselaer Clearway Quiet Closing Check Valve
Features low-friction clear-way and quiet spring loaded closing of the flap ahead of cessation of flow away from the stopped pump.





Pelton's Larner-Johnson Check Valve

Fig. 17—Exterior of this automatic needle-type check. *Fig. 18—Sketch revealing design and functioning of the valve.*

Fig. 19—The Pelton Surge Suppressor A high grade relief valve for use in conjunction with automatic check valves.

joints. The resultant water hammer frequently ruptures the pipe line. The common swing check valve is fundamentally wrong in its design to be of use for such service.

Check valves may be grouped into two general classes: (a) slow closing and (b) quick closing.

Most slow closing valves are, however, impractical, even though theoretically correct. The action of this type of valve with respect to water hammer may be shown by the illustration in Fig. 11. In practice there may be little or no audible water hammer with this type, but as indicated, there is a serious pressure rise due to the surge which may be disastrous to the pipe lines and fittings.

A check valve should generally be of a type that closes *before* the pressure reverses from the immediate low to the quickly ensuing high. Many have found that this is the only type that will give proper service. The quick closing check valve provides for eliminating surge shock at the valve seat, and quickly returns the surge wave to static pressure before any appreciable surge oscillation can be set up in the discharge line. All discharge lines, especially of the larger diameters, are at least to some degree elastic and will permit so-called harmonic surges to develop. When the discharge column of water is halted before a reversal of flow takes place, these surges will not cause a dangerous pressure rise. The action of the rapidly closing type of check valve, with respect to ensuing water hammer, may be illustrated as shown in Fig. 12. These two pressure recordings (Figs. 11 and 12) show that the pressure rise has been reduced from about 50 per cent excess head to about 10 per cent over the static pressure through the effective timing of closure of the automatic check.

The Smolensky Check

One type of check valve used for this purpose is the Smolensky check valve, which is illustrated in Figs. 13 and 14.

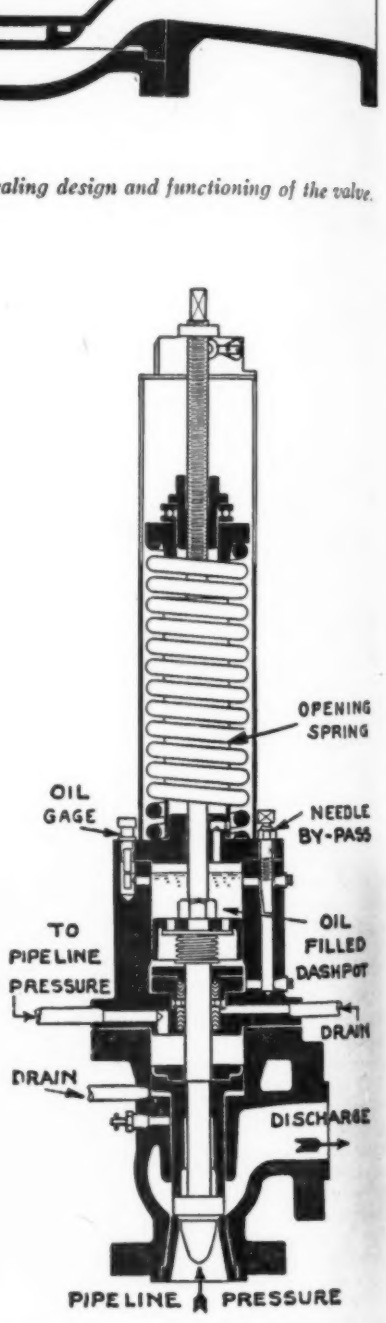


Fig. 20—The Pelton Surge Suppressor Sketch revealing working parts and functioning of this surge dissipating unit.

This valve is designed to close just a little in advance of minimum pressure at the pump, so as to insure absolute freedom of danger of reversal of pump and motor. It also prevents mechanical shock at the check valve for the spring action is counterbalanced by the back pressure against the diminishing pump discharge. The mechanism of this valve is shown in Fig. 14.

The seat position of the Smolensky valve is dependent entirely upon the velocity of the flow and the action may be understood by reference to the homely analogy of a laborer following a loaded truck up a steep incline. By chocking the wheels at the slightest tendency to stop, a small stone is sufficient to hold the load from reversing. Allow the truck to fall back a few feet and the truck load will be in danger, since its stopping is much the more difficult.

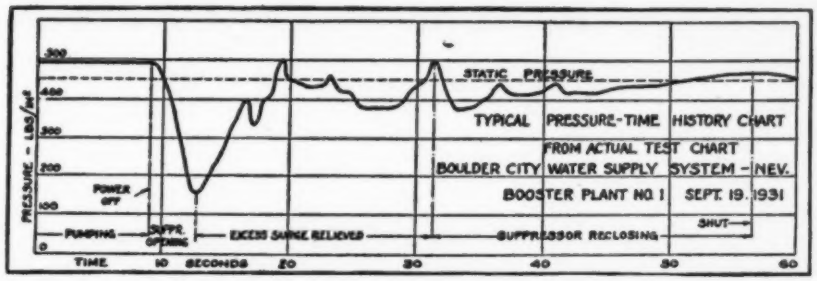


Fig. 21—A Real Performance Record
Showing the result of combination of automatic check and Pelton Surge Suppressor on a heavy duty job under 490 lbs. static head. This race was won in approximately 50 seconds flat.

Rensselaer's Quiet Closing Check

Fig. 15 shows the Rensselaer quiet-closing check valve. When the pump is started the swing check is opened and held out of the flow by the water velocity. On pump shut down the closing spring carries the check valve disc to its seat at the instant the water column in the discharge line comes to rest, thus assuring quiet and positive closure and some reduction in pipe line surges.

Chapman's Tilting Disc

Fig. 16 illustrates the exterior and interior of the Chapman non-slam tilting-disc check valve. This type of check closes with a minimum of slam. Friction losses are also very substantially reduced in the design. The disc is pivoted just above its center, which results in a cushioning effect resulting while closing. This is due to the fact that the portion of the disc above the pivot partially balances the portion below. The seat and disc rings are beveled and the disc drops into the seat in the body with a closing action which gives a further cushioning effect. This valve in closing reaches its seat at exactly zero velocity in the line. The angle of the seat is so inclined that the distance the disc must travel from its wide open position to its seat is reduced to the minimum consistent with good design.

Larner-Johnson Check

Fig. 17 shows the exterior of the Pelton-Larner-Johnson check valve, and Fig. 18 shows how it functions.

This check is normally automatic in operation but may be arranged for manual control. With the control equipment which is built into this type of check valve the time of closing may be regulated to best suit local conditions. It is designed for installation on the discharge side of a centrifugal pump, its best function being to close at the instant of power failure and to prevent both reversal of the pump and motor and wastage of pumped water.

Pelton Surge Relief Valve

In many cases of operating centrifugal pumps, surge and water hammer cannot be eliminated by the mere installation of a check valve alone regardless of type. In such cases it is also necessary to install additional equipment such as an air tank, relief valve or such. For difficult situations one of the best known pieces of equipment for this purpose is the Pelton Surge Suppressor, shown in Figs. 19 and 20. This surge suppressor is essentially a high grade relief valve, designed for use with a check to relieve surge pressure in a pump discharge line incident to pump shutdown. It may be operated either by water pressure, solenoid or mechanical interconnection with the check valve. To permit a sufficiently rapid closure of the check and thereby prevent dangerous reversal of the pump after the power shut-off, the surge suppressor is essential to relieve the resulting pressure surges. The surge suppressor *opens with the drop in pressure* following shutdowns, remaining open to relieve the surge which follows. It then automatically closes at an adjustable rate.

The action of the Larner-Johnson Check Valve and the Pelton Surge Suppressor in combination are shown in the results obtained on the accompanying time-pressure diagram (Fig. 21) of the Boulder Dam water supply to Boulder City. Operating under a static pressure of about 490 pounds, the time-pressure diagram (Fig. 21) shows that it took about 50 seconds only for the pressure head to become normal static head after pump shutdown, during which interval the rise in pressure was not more than 10 pounds above static.

Studying and Recording Surge Conditions

In actual operating practice it is seldom that any two cases of surge or water hammer are identically alike. The simpler cases of surge in building pipe systems may usually be overcome with the low cost type of surge suppressors previously shown. With the more complicated cases, especially those affecting water distribution systems, the conditions become very involved and it is usually necessary to make a complete survey of the actual facts pertaining to each individual case before it can be properly handled. It is necessary to determine the amount and intensity of water hammer and thereafter take new records in order to determine the results obtained from equipment installed, or other corrective measures applied.

For this purpose it is essential to employ equipment for recording pressure-time diagrams of the disturbance. Fig. 22 shows Bachrach's Chronomatic Drum, which gives a pressure-time diagram, revealing clearly the pressure pulsations in the pipe line during a certain time interval. Fig. 23 shows this equipment in carrying case for ready portability. This is a time-pressure indicator originally designed for testing high-speed diesel engines. It has unrestricted speed selectivity and instantaneous speed indication. The operation is simple and requires no skill or special training. The time-pressure diagram for the Boulder City line was taken with this equipment.

Few engineers have had wide contact with problems calling for relief from water hammer in pipe lines or piping systems. The present literature on the subject is neither broad nor inclusive, being largely devoted to the extreme technical and theoretical phases of the subject. On this account it has been my purpose to confine this discussion to a few practical considerations.

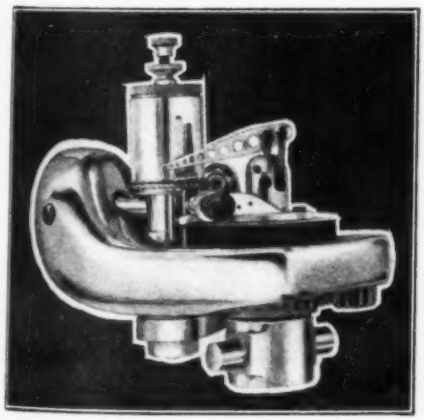


Fig. 22—Bachrach's Chronomatic Drum
Its use provides the all important time-pressure chart in studying water hammer and attainments resulting from corrective measures and functioning of equipment.

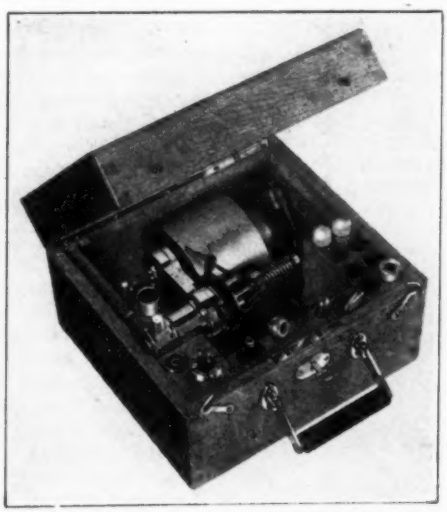


Fig. 23—Bachrach's Portable Recorder
Is compact and useful in surge study on pipe lines and distribution systems.

THE ELIMINATION OF CHECK VALVE SLAM

By H. K. PALMER*
Los Angeles, Cal.

The slamming of check valves when pumps are stopped constitute a source of annoyance and often of expense to water works or sewage works, and allied institutions. Many check valves have an annoying habit of slamming when it is least expected, while others placed on long lines may close quietly. Too sudden closing may easily cause a rupture in a pipe line, a feature which may be eliminated by inclusion of a large air chamber which will eliminate sudden pressure on the pipe but may cause such an abrupt closing of the valve as to crack the flap.

Check valve slam produced by a surge in the water column causes water hammer, with its consequent damage. When a pump suddenly stops, the water tends to continue in motion due to its momentum, and the gage pressure drops to zero. The force tending to stop the motion of the water is proportional to the static head on the pump and such force produces a negative acceleration in the water column according to the formula:

$$F = Ma$$

where: F = Force producing acceleration; M = Mass of water; a = Acceleration.

Letting: A = Area of pipe, square feet; L = Length of pipe in feet; g = Acceleration due to gravity (32.2); w = Weight of a cubic foot of water (62.4 lbs.); h = Static head on the pump; Hf = Friction head; H = Total head; t = Time in seconds; v = Velocity in pipe:

One may: compute the force producing acceleration as being

$$F = h\,A\,w$$

And, the mass of water is found to be

$$M = \frac{A\,L\,w}{g}$$

Then:

$$h\,A\,W = \frac{A\,L\,w}{g}\,a$$

Or

$$a = \frac{h}{L}\,g \qquad \text{(See Figue 1)}$$

If v is the velocity in the pipe before the pump stops, the time (in seconds) required to bring the water to a stop will be

$$t = \frac{v}{a}$$

If the flap can come to its seat in (t) seconds or less, it is obvious that the water cannot move backwards and as the flap is moving against the stream it will be cushioned. On the other hand if the flap does not have time to become seated within (t) seconds, the water will start backwards and the valve will close with a slam.

Rapid vs. Slow Closing Checks

It is obvious that what is desired is *a valve that will close rapidly*. One way to accomplish this is to have the valve seat inclined to shorten the distance the flap must move, and another is to use a valve with an extended hinge pin and arm so that the flap can be weighted. This weight prevents the flap from opening fully, causing a small increase in pressure, but accelerates its return movement when the pump stops. On one test in which a four-inch pump was forcing water into a pneumatic tank under 65 pounds pressure, the slam was eliminated by hanging enough weight on the check hinge pin arm to increase the pumping pressure less than one-half pound. This represented one of the most difficult situations for slam elimination because the pump line was short and there was little mass to the flowing water; thus in one controlling formula $a = \frac{F}{M}$, (a) was relatively large; and in the other formula $t = \frac{v}{a}$, (t) was relatively small.

Where it is not practicable to close the check valve in less than time (t), the use of *a slow closing valve* should be considered, but such valves are expensive and must be so designed that the final closure is made very slowly. An air chamber will provide a cushion in case the valve does not close before the flowing water comes to rest and will protect the pipe against excessive pressure. Immediately after the pump stops, the value of the shock absorbing compressed air in such chamber is its cushioning effect, which tends to maintain the gage pressure on the line instead of allowing it to drop to zero. It will thus delay the stopping of the water in the main pipe but the pressure being maintained close to the pump, where the air chamber will normally be placed, produces excessive acceleration in the short length of pipe between the chamber and pump and although the valve will slam violently, the pressure on this section of the pipe will not be excessive. After the valve has slammed the water in the main pipe will slowly come to rest, and then back into the air chamber, the gage showing an oscillation about the static elevation, as a center, with maximum and minimum at approximately $(h + H_f)$ and $(h - H_f)$.

The air cushion in Fig. 1 has purposely been drawn much larger than is recommended in order to illustrate the conditions. If, instead, it consists of a piece of pipe of the same diameter as the discharge pipe and about two or three diameters in height it will not supply enough water to permit any to flow backward through the check valve, thus avoiding a slam and at the same time preventing excessive pipe pressure. A surge will be set up with a maximum pressure of $(H = 2h)$ and minimum $(H = o)$.

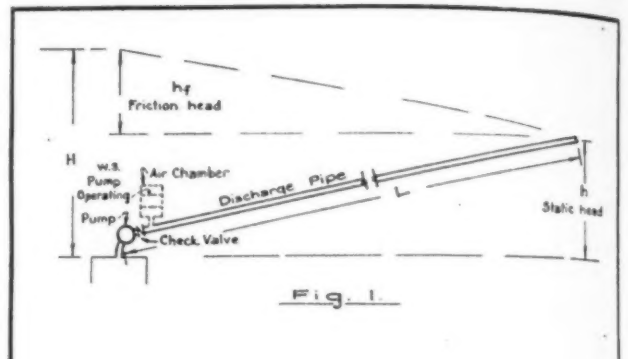


Fig. 1.

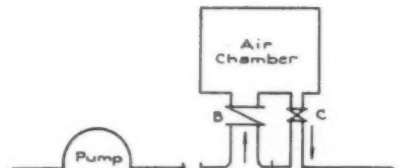


Fig. 2.

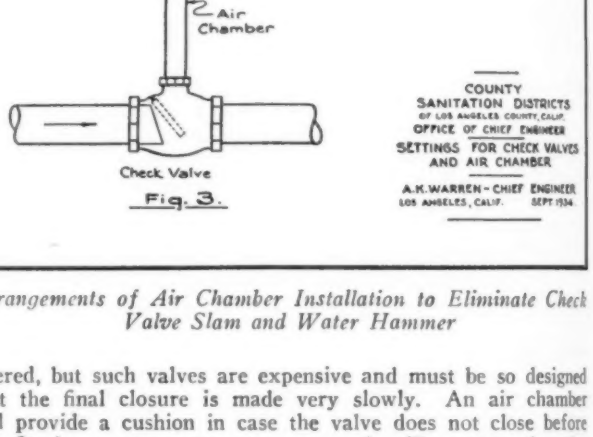


Fig. 3.

Arrangements of Air Chamber Installation to Eliminate Check Valve Slam and Water Hammer

*Chief Draftsman, Los Angeles County Sanitation Districts.

A Successful Arrangement

An air chamber arrangement which has been found to work very successfully is shown in Fig. 2. "A" is the main line check valve, "B" a check valve into the air chamber which should be nearly as large as "A" and set to allow water to enter the chamber. "C" is a gate valve or a plug cock smaller than "B." "C" must be opened or closed by trial until it limits the flow of water from the air chamber enough to prevent slamming of valve "A," and thereafter left in that position. The limited supply to the pipe damps out the surge, yet check valve "B" is large enough to admit a full stream to the air chamber and thus prevent excess pressure on the return flow.

To correct slam in an existing check valve, an air chamber can be built into the cover plate of the valve (Fig. 3). Care must be taken to so adjust the size of such a chamber that sufficient water is returned to close the flap by the time the water comes to rest but not sufficient to produce a slam.

This investigation was made about five years ago by the writer for the Los Angeles County Sanitation Districts and the data obtained applied to the correction of a number of troublesome conditions where valve slam was a problem.

The writer is indebted to E. A. Rutledge of the Rensselaer Valve Company for testing the formulae on many successful water works installations. A. K. Warren is Chief Engineer and General Manager of the Sanitation Districts and A. M. Rawn is Assistant Chief Engineer.

CHECKING WATER HAMMER*

When the water flowing through a pipe is stopped very suddenly there is rise in pressure in the pipe line that may at times amount, roughly, to 50 times the velocity in feet per second at which the water is moving at the instant.

The best cure for water hammer is a slow-closing valve. The next best cure is to provide an air chamber located as close as possible to the valve. If kept fully charged, an air chamber is considered to be of sufficient size when its capacity is one per cent of the pipe line it serve to cushion. Means of renewing the air cushion must be provided for.

Required Volume of Air Chamber

The size, that is, the volume, of an air chamber depends upon a number of factors of which the principal ones are:

The length and size of pipe that the air chamber serves.

The rate of flow of water through this pipe.

The pressure in the air chamber immediately preceding the stopping of the flow, and the pressure due to the stopping of the flow, and,

The nature of the action that puts the air chamber into service—whether it be instantaneous, or rapid, or prolonged.

The following treatment is based upon the first three factors. With reference to the fourth factor—it is the more or less instantaneous stopping of the flow that makes necessary the use of an air chamber. Hence, we are virtually assuming the condition of rapid closing. By this method a volume of air chamber is determined such that the energy of the moving water is absorbed between prescribed limits of pressure in the air chamber.

We have the expression,

$V = L \times P \times R^2$, in which

V is the internal volume of the air chamber in cubic inches,

L is the value from Table 59 for the size and length of pipe that the air chamber serves,

P is the value from Table 60 for the flowing pressure and the assumed maximum pressure, both in the air chamber, and

R^2 is the square of the rate of flow through the pipe in gallons per minute immediately before the stopping of flow.

Note—The flowing pressure can be determined approximately by deducting from the static pressure at the air chamber the loss of pressure in the run of piping (for which the size of an air chamber is being found) under the assumed rate of flow.

Determine the size of an air chamber for a ¾-inch branch, 20 feet long, carrying 10 gallons per minute, based on pressures of 20 pounds per square inch flowing, and 60 pounds per square inch maximum.

Substituting,

$V = 0.042 \times 1.6 \times 10^2 = 6.7$ cubic inches.

Having determined the volume of the air chamber, it becomes necessary to fix the proportions—whether to make it of relatively small diameter and correspondingly long, or short and or 12 6 inches. Sectional area of ¾-inch pipe is 0.53 square inch from Table 61.

TABLE 59
Values of L

Length of Run, Feet	Size of Pipe, Iron Pipe Size ½	¾	1	1¼	1½	2	2½	3	4
10.....	.037	.021	.013	.0074	.0055	.0033	.0023	.0015	.0009
20.....	.074	.042	.026	.015	.011	.0066	.0045	.0030	.0017
30.....	.111	.063	.039	.022	.016	.010	.0068	.0045	.0026
40.....	.148	.084	.052	.030	.022	.013	.0091	.0060	.0035
50.....	.185	.105	.065	.037	.027	.017	.011	.0075	.0044
60.....	.222	.126	.078	.044	.033	.020	.014	.0090	.0052
80.....	.296	.168	.104	.059	.044	.026	.018	.012	.0070
100.....	.370	.210	.130	.074	.055	.033	.023	.015	.0087
125.....	.462	.262	.162	.093	.068	.041	.028	.019	.011
150.....	.555	.315	.195	.111	.082	.050	.034	.023	.013
200.....	.740	.420	.260	.148	.109	.066	.045	.030	.017
250.....	.924	.524	.324	.185	.136	.082	.057	.037	.023

Note that for each size of pipe value of L is proportional to length of run.

TABLE 60
Values of P

Maximum Pressure, Lb. Sq. In.	Flowing Pressure, Lb. Sq. In. 15	20	25	30	35	40	50	60	80	100
20..	42.									
25..	12.	56.								
30..	6.0	16.	72.							
35..	3.8	7.8	20.	90.						
40..	2.6	4.8	9.8	25.	110.					
50..	1.6	2.5	4.2	7.3	14.	36.				
50..	1.1	1.6	2.5	3.8	6.0	10.	49.			
80..	0.67	0.92	1.3	1.7	2.4	3.3	6.9	18.		
100..	0.48	0.63	0.82	1.1	1.4	1.8	3.0	5.4	27.	
120..	0.37	0.47	0.60	0.75	0.93	1.2	1.8	2.8	8.0	39.

TABLE 61
Sectional Area of Pipe

Size of Pipe Iron Pipe Size	Area of Internal Cross-Section of Pipe Sq. In.
½	0.30
¾	0.53
1	0.86
1¼	1.50
1½	2.04
2	3.36
2½	4.78
3	7.39
4	12.7

(The above article should be useful in meter shop practice and otherwise, where quick closing valves must be employed.—*Ed.*)

*From "Water Supply in Buildings," by Alex. W. Moseley, Mass. Inst. of Technology, 1935.

"dumpy." If made of ¾-inch pipe, length would be 6.7/0.53,

COMPUTING HORSEPOWER FROM REVOLVING WATT-HOUR METERS

A simple method of accurately measuring power consumption is of general interest to the owner or operator of any electrically driven pump. A periodical record of the power consumption, capacity of the pump, and the measurement of the pumping level assists in maintaining operation at maximum efficiency and gives an indication as to the proper time for reconditioning or modernizing the installation.

The power consumption is measured by the Watt-Hour Meter, usually located on the switchboard in the pump house adjacent to the motor. Large units require current and/or potential transformers, so that the watt-hour meter reading must be multiplied by the ratio of these transformers to obtain the correct measurement of power consumption of the motor.

A motor which draws 200 amp. at 440 volts may be metered through current transformers rate 200 amp. primary and 5 amp. secondary, so that 5 amp. would pass through the watt-hour meter. No potential transformers being used, the watt-hour meter reading, multiplied by the ratio of 200 to 5, would give the amount of power in the main circuit.

Asssuming that a motor draws 600 amp. at 2300 volts, potential as well as current transformers are required. If the ratio is 60 to 5 amp. on the current, and 2300 to 115 on the potential transformers, the watt-hour meter reading multiplied by the ratio of 60 to 5 and in addition, by the ratio of 2300 to 115, will give a true measure of the power consumption in the main circuit. The correct ratio is usually stamped on a brass nameplate attached to the transformer.

Disk constants and multipliers for practically all modern watt-hour meters now in use for single and three phase, 110-220-440 volts are shown in the chart below.

Use of Chart

First determine the make, type, volts and amp. of the meter. If no current or potential transformers are used, refer to the chart and determine M value for the meter. The M × r.p.m. of disk = hp. input to motor for example, a meter, G.E., type D-3, 220 volt, 15 amp., K = 4.0, M = .3217, number of revolutions of disk in one minute = 20. Then .3217 × 20 = 6.434 h.p. input to motor.

As another example consider an installation where current transformers having a ratio of 20 to 1 are used. Meter, Westinghouse type OA, 220 volt, 5 amp., K = 1⅓, M = .1027, number of revolutions of disk in one minute = 21. Then, .1072 × 21 × 20 = 45.02 h.p. input to motor.

Disk constants K are included in the accompanying chart because occasionally the manufacturer's nameplate has been removed, in which event the constant K is marked on the meter. To determine the M value in such cases, find a K in the table corresponding to that on the meter in question. The M applying will be the one adjacent to and on the right of this K.

Definitions:

K—A constant which represents the number of watt-hours passed through the meter while the disk makes one revolution.

M—A factor which, when multiplied by the number of revolutions of the disk, in one minute, gives h.p. **input to motor.**

Mathematically, $M = \frac{K \times 60}{746}$

The h.p. values expressed above relate to input to motor. The rating of motors is in terms of h.p. output. Therefore, the h.p. output or brake h.p. is determined by multiplying the h.p. input by the motor efficiency, which can be obtained from the motor manufacturer.

Chart of Constants and Multipliers

For Use in Determining KW Input, HP Input or BHP from Revolutions of Watthour Meter Disks

110 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.3	.0241	.25	.0201	.3	.0241	.6	.0483	5/24	.0168	⅓	.0268
10	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
15	1.0	.0804	.75	.0603	.9	.0724	1.8	.1448	5/8	.0503	1	.0804
25	1.5	.1206	1.25	.1005	1.5	.1206	3.0	.2413	2 5/24	.0838	1⅔	.1340
50	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681

220 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
10	1.25	.1005	1.0	.0804	1.2	.0965	2.4	.1930	5/6	.0670	1⅓	.1072
15	2.0	.1609	1.5	.1206	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681
50	6.0	.4826	5.0	.4021	6.0	.4826	12.0	.9651	4 1/6	.3351	6⅔	.5362

110 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.6	.0483	1.2	.0965	5/12	.0335	2/3	.0536
10	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
15	2.0	.1609	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	3.0	.2413	6.0	.4826	2 1/12	.1676	3 1/3	.2681
50	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362

(*Continued on next page*)

220 Volt—Three Phase

Amp.	General Electric D-3 K	General Electric D-3 M	General Electric D-6 & D-7 K	General Electric D-6 & D-7 M	General Electric D-14 K	General Electric D-14 M	Sangamo H K	Sangamo H M	Westinghouse C, OA, OB, RO. K	Westinghouse C, OA, OB, RO. M
5	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
10	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
15	4.0	.3217	3.6	.2895	7.2	.5791	2 1/2	.2011	4	.3217
25	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362
50	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072

440 Volt—Three Phase

Amp.	General Electric D-3 K	General Electric D-3 M	General Electric D-6 & D-7 K	General Electric D-6 & D-7 M	General Electric D-14 K	General Electric D-14 M	Sangamo H K	Sangamo H M	Westinghouse C, OA, OB, RO. K	Westinghouse C, OA, OB, RO. M
5	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
10	5.0	.4021	4.8	.3861	9.6	.7721	3 1/3	.2681	5 1/3	.4289
15	7.5	.6032	7.2	.5791	14.4	1.158	5	.4021	8	.6434
25	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072
50	25.0	2.011	24.0	1.930	48.0	3.861	16 2/3	1.340	26 2/3	2.145

$$\text{hp. Input} = \frac{\text{"M"} \times \text{Revolutions per minute of Disk}}{\text{Sec.} \times 746}$$

$$\text{hp. Input} = \frac{\text{"K"} \times \text{Number of Revolutions} \times 3600.}{\text{Sec.} \times 746}$$

Important—Where instrument transformers are used, be sure that figure computed from revolutions of disk and table be multiplied by ratio of instrument transformers.

(From Byron-Jackson Bulletin, "Deep-Well Turbine Pumps.")

DEVICE FOR FEEDING LIME SOLUTION INTO MAINS

By E. T. CRANCH
Manager, New Rochelle Water Co.
New Rochelle, N. Y.

THE New Rochelle Water Company purchases its water from the Croton System of New York City. This is an impounded supply with a normal pH ranging from 6.8 to 7.2.

In order to absorb the free CO_2 and thus reduce the corrosive character of the water The New Rochelle Water Company treats all the water it takes from the Croton Aqueduct with lime to maintain a pH of 8.6. The water is lifted from the Croton Aqueduce by means of pumps located about 15 feet above the water level in the aqueduct. A saturated solution of lime water is continuously fed into the suction line. It was found that lime would build up in the feed piping. By closing the corporation cock all the piping could be easily cleaned except the corporation cock itself, which became badly plugged and it was almost impossible to clean it without shutting down the pumps and losing the suction. As it takes about an hour to prime the suction header after the suction has been lost the station operators never liked to work on the corporation cock.

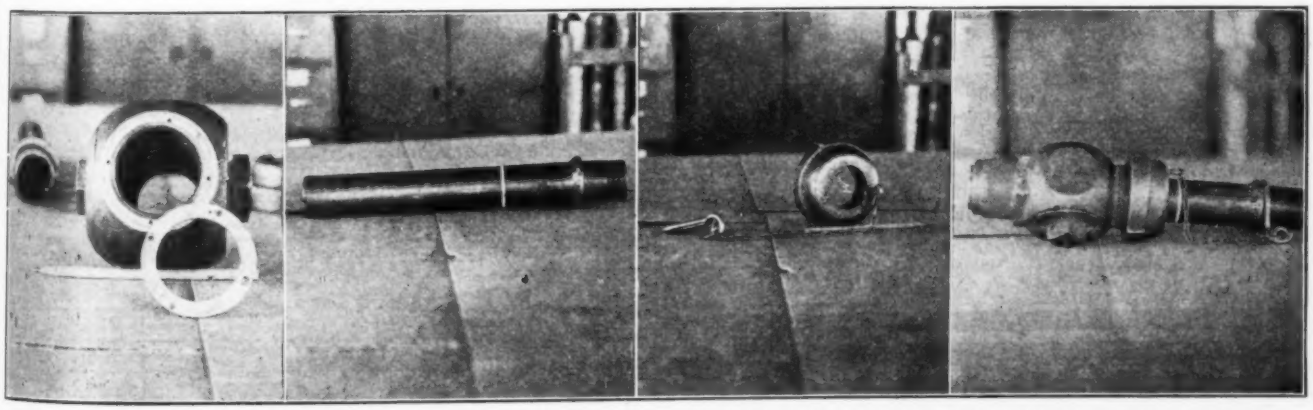
Then it was suggested that a connection to the suction line be made up similar to the usual type of device for feeding chlorine solution. Accordingly Mr. Charles Neydl, who has charge of the Meter Repair Shop, made the device illustrated.

Method of Installation

The device has a tube which slides through a gland and corporation cock and projects into the main. It can easily be withdrawn under pressure, or suction, cleaned and returned.

In order to insert this unit it was necessary to remove the old 1½ inch corporation-cock, drill out the old hole in the 30-inch cast iron suction line to fit a 2-inch corporation-cock and insert the new 2-inch cock. All this was done with a regular Mueller tapping-machine, with the loss of very little suction.

After the tapping machine was carefully centered over the existing 1½-inch corporation-cock the pumps were shut down and the vacuum priming device started. The 1½-inch cock was then removed by use of an extracting plug. Of course the check valve in the tapping machine did not hold against a negative pressure, but this was overcome by placing a board across the open end of the barrel of the tapping machine as soon as the top was removed. In this way so little suction was lost that the priming device had the pumps ready to start again by the time the insertion of the 2-inch corporation-cock was completed.



(1) 2-in. Corporation cock fitted with stuffing box plate exactly to fit 1½-in. Wrought Iron pipe. (2) 1½-in. Wrought Iron pipe with ring welded on it for stop-chain. White painted band indicates correct amount of insertion when feeding lime. (3) 2½-in. Cap drilled exactly to fit 1½-in. Wrought Iron pipe and equipped with rings and stop-chain. (4) Assembled Unit.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

MFGR. NO. _____ CO. NO. _____ MAKE _____ SIZE _____

DATE PURCHASED _____ STYLE _____

INSTALLATION RECORD								TEST AND REPAIR RECORD							
INSTALLED		NAME	ADDRESS	Tap No.	Reasons for Removal	Removed		Date	Rate of Test			Repairs		Total Amt. of Water Passed Before Test	Tested By	REMARKS
Date	Reading					Date	Reading		Min. Flow	Inter. Flow	Max. Flow	Before Test	After Test			

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. Insert Meter in Tester—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. Flush Meter Out With a Large Flow—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. Bring Test Hand of Meter to a Mark—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. Make a Record of the Tests—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the previous page.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW

By P. S. WILSON

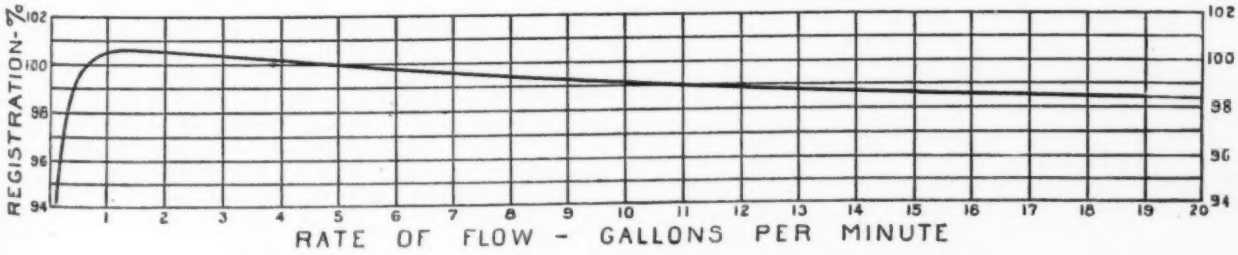
Water Works Consultant, Glen Ridge, N. J.

A TYPICAL registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole.



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of the three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test, these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufactuirng methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

TABLE I

Rates of Test Flow. From Standard Specifications for Cold Water Meters, Disc Type, Adopted by the A. W. W. A. June 19, 1921, and by the N. E. W. W. A. Sept. 14, 1921

Size of Meter (Inches)	Normal Test Flow Limits (Gallons per Minute)	Minimum Test Flow (Gallons per Minute)
⅝	1 to 20	¼
¾	2 to 34	½
1	3 to 53	¾
1½	5 to 100	1½
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice—Inches	Pressure—Pounds Per Square Inch— 40	60	80	100
1/32....	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16....	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8....	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16....	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4....	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16....	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8....	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16....	22. —36.	27. —44.	31. —51.	34. —57.
1 /2....	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressure. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand, if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with round edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

SELECTING THE RIGHT METER

By ROGER W. ESTY

Superintendent, Water Works and Sewerage, Danvers, Mass.

In days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

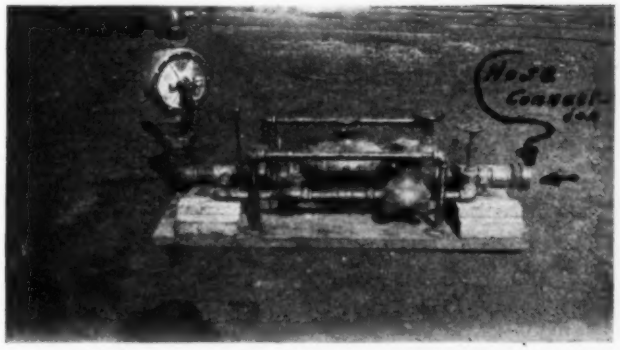
Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizeable and serious loss.

In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.

Neptune Recording Meter Set, Used in Evalulating Variations in Water Takings by a Customer and Determining the Proper Capacity of Meter



Portable Meter Testing and Flow Measuring Outfit Used in Field Tests

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 g.p.m. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 g.p.m. and on the 8-inch meter 75 g.p.m.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch

meter would suffice on the 8-inch service. But, these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the first might be.

We have had these smaller meters in now for nine years and we have only opened up the unmetered side of the line once. At this fire only one stream was used, but the gate was opened just the same. No difference was noticed in the volume in this instance, where a 3-inch meter had been cut into a 6-inch line leading from an 18-inch main.

What Size Service Line?

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand, should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 g.p.m. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 g.p.m. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

[For the correct size of service line for a given demand a useful chart appears in Part III of the 1942 issue.—Ed.]

Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

A SMALL METER SHOP

Room Built and Equipped for the Needs of a Department With 3200 Metered Services at Cost of $1500

By ROGER W. ESTY

Water and Sewer Board, Danvers, Mass.

THE Town of Danvers is situated in the northeastern part of Massachusetts, has a population of 15,000, and is a farming and industrial community, with considerable historical background.

The water system, started back in 1876 with some twenty miles of pipe and about 500 services, today covers 67 miles and has 3,200 metered services. Our consumption started off with about 120,000,000 gallons per year and increased to an annual consumption of 550,000,000 gallons during the 1920's. Metering, which was begun in 1922, has caused water waste and total consumption to drop some every year until now Danvers uses only about 360,000,000 gallons annually.

For years, while our consumption was decreasing and our metering was increasing, our revenue kept increasing until it became permissible to reduce our service charge 20 per cent. Later the meter rate was cut 25 per cent, and it will be necessary in the very near future to again reduce our rates.

All of this is the result of planned metering. Up to two years ago we had no meter testing room in which to test, store, and maintain our meters. Most of our meters—70 per cent—have only been in about five years, and we felt it was becoming necessary to build and equip a modern, up to date testing room to properly maintain them.

Our Compact New Meter Shop

Well, what is different with our testing room than what you may have? It may be different in one respect, and that is, we are starting off with everything new. Three years ago we were planning for a new shop building but it just didn't materialize, so the Board decided that they would build and equip an up to the minute meter room within our present shop building. For the purpose $1,500 was voted to equip it.

Outside of our commercial meters we only had about 1,000 meters from 1922 to 1934. Then we started to install a few hundred each year until we had 3,200 meters in service by 1938.

The pictures accompanying this article illustrate our present set-up which we feel meets our needs in a satisfactory and efficient manner.

The room is 21 feet 3 inches long by 11 feet wide with Homasote wallboard walls, stained hardwood floor, three windows equipped with venetian blinds and two doors. So, first of all, it is light and airy. For artificial light it is lighted by fluorescent lights.

We installed a three meter Ford testing machine and Ford's Testerate device, which regulates the testing flow in gallons per minute, a 10 cubic foot tank and 1 cubic foot tank.

In the corner of the room, between the meter testing machine and bench, we constructed a wooden washing sink, which is 3 feet 4 inches by 1 foot 8 inches by 36 inches high.

Our bench is 12 feet 4 inches and 2 feet 5 inches wide and is 3 feet high. It is constructed out of oak and is covered with a steel top. It has a meter-holder on the end over the sink, where the meters are taken apart, and a small vise is located near the same end. At the other end is a portable drill press and a portable grinding and brushing machine.

Under the bench top near the sink is a drawer for the every day tools. Then an empty space to sit before, so your legs can go comfortably under the bench. Under this section is our air line hose coming in from the garage. We find the air hose a highly important and useful part of meter shop equipment because it is very essential to have air to properly clean and dry out the disc chamber for proper fitting. Also air is useful for operating a meter for any purpose, particularly the "running in" of discs.

Storage Shelves

Then we have what we call our "bakers wagon shelf-storage," a series of shelves, grooved and slotted to hold gear trains, registers, covers, discs, and chambers. This is the finest method of storage that I have been able to find or devise. With this scheme many supplies can be stored in a very small space.

The next section is made up of three drawers for miscellaneous storage, equipment, and tools.

Record File Handy in Shop

At the end of the bench is sufficient space for a steel desk which contains a card file of all of the meters. These record cards show a complete meter history as to where and when installed, when the meter has been taken out to be tested; also the results of the tests, with a list of all material used in making changes or repairs. This desk also serves as a place to do the necesary book work by the meter-man and a place to keep his test books, etc.

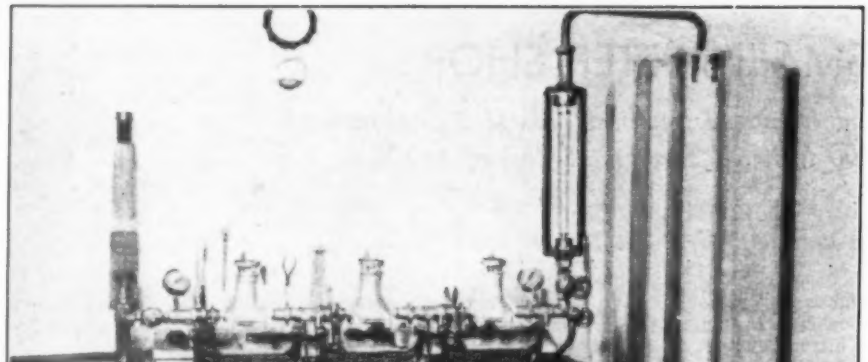
Along the other side of the room are three sets of steel shelving which is ample storage for all active meters. That is, those

Convenient method of storing meter parts. We call it our "baker's wagon," after which it was patterned.

The wash-sink in a corner; meter holder for dismantling; cleaning gadgets and handy roll of paper towels. The ivy adds a touch.

Work bench with record file and desk in corner. Portable drill press, grinding and brushing machine—and plenty of tools and light.

Views of the Danvers Meter Shop



Our Three-Unit Ford Testing Machine
Equipped with flow indicating "Testerate" unit, above, discharging into calibrated 10 cu. ft. and 1 cu. ft. measuring tanks. This set up is a "honey."

brought back from summer service for winter storage, and from houses where service has been discontinued for an indefinite period. There are seven shelves, each supplying space to store 250 meters.

We read all of our meters by districts, as we have the town divided up into A, B and C sections, and so we have assigned Section 1 for meters in District A, and Sections 2 and 3 for Districts B and C.

All inactive meters are stored away in another room, which leaves this room entirely for active material, which plan makes for better "housekeeping."

At the end of the storage racks we have a cabinet of ten drawers, all divided up

DANVERS WATER WORKS

Make .....

..... | Number ..... | Order No. .....
..... | Reading B. T. ..... | Acct. No. .....
..... St. | Reading A. T. ..... | Tap No. .....
Date Tested .....

Number of Cubic Feet	Discharge G. P. M.	PRESSURE Inlet	PRESSURE Outlet	%	REMARKS

..... 194.... ..... Inspector

Meter Test Record Form

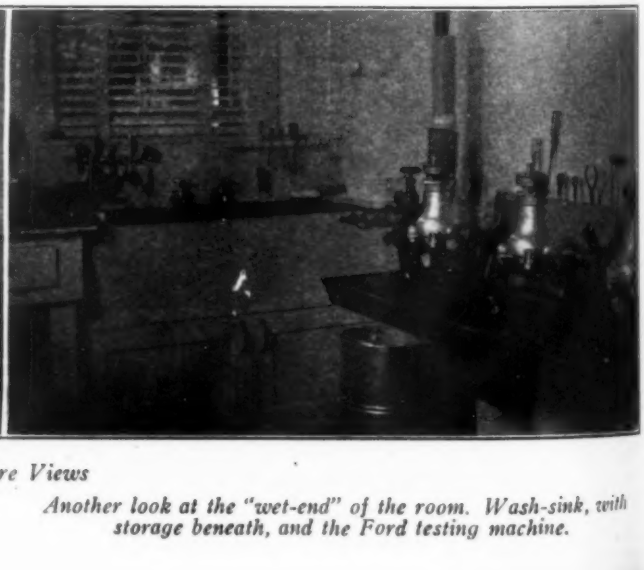
DANVERS WATER WORKS

Name .....
Address .....
Size & Make .....
Number .....
Reading .....
Date .....
Remarks .....
.....
By .....

DANVERS WATER WORKS

Name .....
Address .....
Size & Make .....
Number .....
Reading .....
Date .....
Remarks .....
.....
By .....

Meter Record Card and Stub



Two More Views

Looking "aft" down the bench. A close look will reveal the highly useful air hose at the central working space.

Another look at the "wet-end" of the room. Wash-sink, with storage beneath, and the Ford testing machine.

into small compartments, which holds the small parts of the registers, gear trains, discs, etc. Over our bench we have three sets of very small drawers, which hold several sizes of change gears and some parts of the discs and gear trains.

This description, I feel, will give a pretty good idea of what we feel a well fitted meter testing room should have, to test and maintain 3,000 meters. The only difference that I can see between what we have and a city having, say, 7,500 meters would be: first, a testing machine of greater capacity; second, a little larger bench; and third, additional storage facilities.

Design to Save Steps and Loss Motion

Make your room cozy, don't make it too barny. Arrange the testing machine, washing basin, and repair bench close together. It saves time and steps, steps—and this is very important. I have seen meter rooms in which the meter man spends far too much of his time walking back and forth and back and forth from one operation to another.

Our meter room is the result of my observations in a great many other water plants and from the many helpful suggestions we have received from superintendents and meter-men who actually do the testing. I am indeed very grateful to them, and I extend an invitation to all water works men to visit or meter room, for it may offer some thought or suggestions toward even a better set-up than we have here at Danvers.

In my travels, interviews and correspondence there seems to be no fixed standard procedure in testing, and, furthermore, no one in authority (like a sealer of weights and measures) ever checks up to see whether or not the meter has been properly and thoroughly tested to the mutual interests of the customer and the utility.

Samuel F. Newkirk of Elizabeth, N. J., is chairman of the Joint Meter Specification Committee for the A.W.W.A. and N.E.W.W.A., and his committee has essentially completed a new set of specifications that are more rigid in certain directions and more flexible in others, than those of the past.

In the August issue of WATER WORKS AND SEWERAGE there is an article on "Water Meter Maintenance Practice" that was recently read at the A.W.W.A. Toronto convention, which is very timely. It is the result of a survey by A. P. Kuranz, Superintendent of the Waukesha, Wis., Water Department, made to secure a cross-section picture of meter maintenance policies and practices in this country.

Why Not "Standards of Testing Procedure"?

The thought has occurred to this writer—why not have the present committee also develop "Standards of Meter Testing Practice," to serve as a pattern in equipping meter-test shops of various sizes, and a guide in the proper and most dependable procedures and operations in actual routine testing practice? To the writer, at the time of designing and equipping the Danvers meter-room, and to many others contemplating new meter shops or revamping existing ones, such a guide would prove of high value and usefulness. It will also go far toward bringing standardization and better practices into the important field of metering, where there appears to be room for much improvement and a real need for standardization.

ELECTRIC HEAT SOLVES PROBLEM AT PUMPING STATION

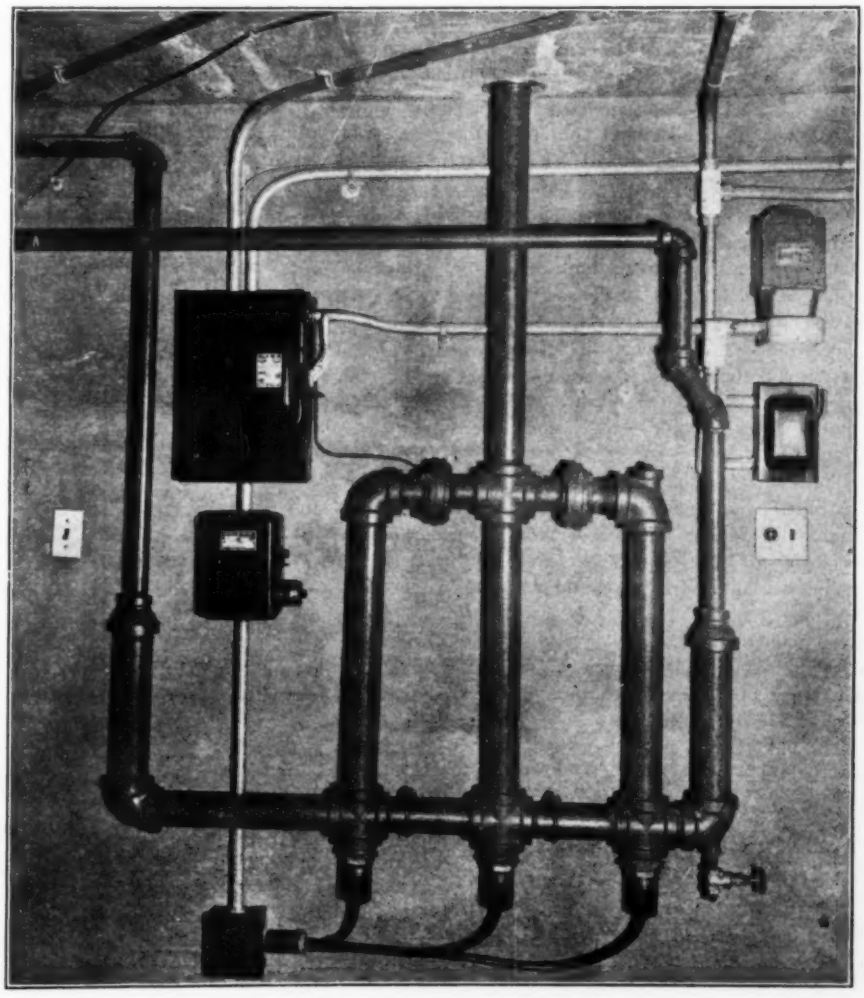
ELECTRIC heat proved the answer to a heating problem recently presented at the plant of the South Bay Consolidated Water Co. at Bayport, Long Island. This pumping station contains two rooms on the ground floor and a basement. One of the two ground floor rooms serves as an office, and the other is the chemical feeder room, separated from the first by a brick partition.

Since the chemicals stored in this second room are of a nature to attack almost any metal except cast iron, it was decided that the best method of heating the room would be by using cast-iron radiators. It was decided to build an immersion heater "electric furnace" in the basement to supply hot water to the radiators in both first floor rooms.

Three G-E electric water immersion heaters are used to heat the water in this ingenious furnace. The hot water riser leads from the top of three heater-enclosing pipes to the radiators on the main floor. The returns lead back to the bottom of the furnace, providing a neat, compact circulating system. An expansion tank is connected to each of the radiators in the first floor rooms. The radiator capacity is so arranged that the expansion tank can take care of the water expansion under any operating condition.

A magnetic contractor handles the heater load, and is controlled by a thermostat located in the operating room above.

A very clear view of this "furnace," with its electric and water connections, is shown at the right.

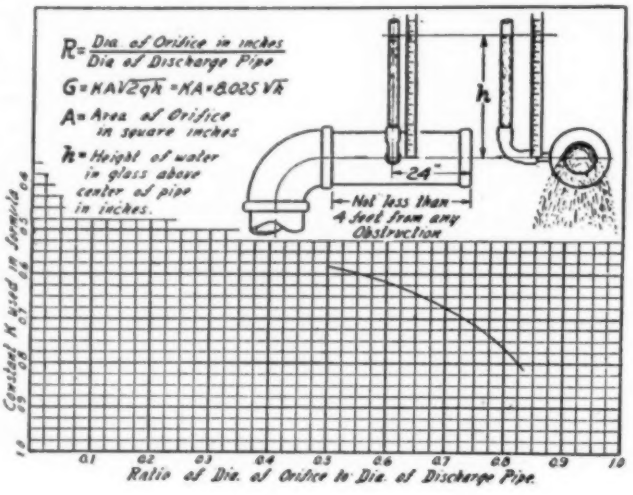


MEASURING FLOWS BY THE ORIFICE METHOD

The orifice method is a simple way to measure flow of water from a pipe discharging horizontally into the open air. The sketch shows the general arrangement.

A plate or cap is affixed to the end of the pipe with the circular orifice in the exact center of the pipe. The size of orifice should be from one-half to three-quarters of the size of the pipe, but must be of such size that it will run full of water.

A hole for ⅛-in. pipe should be drilled and tapped 24 in. back from the orifice and a short ⅛-in. nipple screwed in until the inner end is exactly flush with the inner wall of the pipe. One end of a piece of rubber hose is slipped over the end of the nipple and the other end over a glass tube, which should be supported in a vertical position.



Ratio R is the diameter of the orifice divided by the inside diameter of the pipe, and the proper value of K is found from the curve. In the formula A is figured as the area of the orifice in square inches, G = 32.2, and H is read as the height in inches of the water in the glass tube above the center of the pipe. Gallons per minute (g) then can be figured.

For convenience when determining capacities during pumping tests, the accompanying table for various orifices commonly employed will prove useful.

ORIFICE TABLE FOR DETERMINING WATER FLOW

CLEANING METER CASINGS BY SAND BLASTING*

THE use of sandblasting instead of acid dipping for cleaning meter casings being desirable, it was necessary to develop a chamber that can be used in the meter repair shop so that the work may be done without subjecting the men to silicosis. The illustration is a diagrammatic sketch of the chamber developed by the bureau.

The meter is placed on the notched revolving table and revolved by inserting the end of the blast gun in the notches. As there is some play in the hole through which the blast gun enters the box, a vertical strip 2 inches wide may be cleaned before it is necessary to revolve the table.

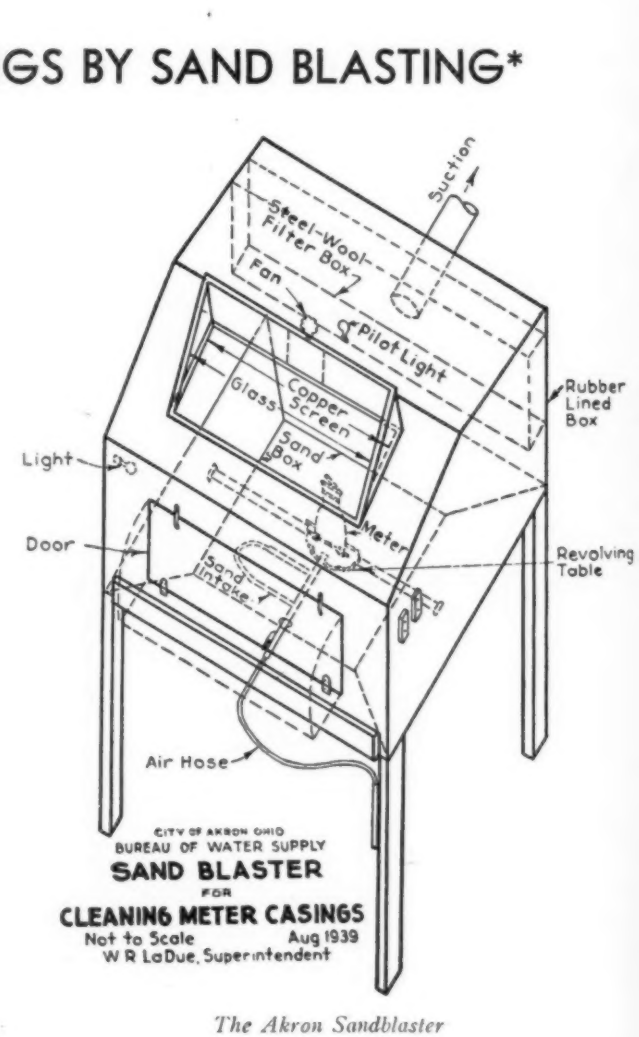
The registers are removed before the casing is placed in the blaster and the bonnet glass and threads on the inlet and outlet are covered, thus no sand enters the casing and the glass is not etched. The cleaning of a ⅝-inch meter requires about three minutes.

The operator looks through the glass window, the glass being protected by a fine mesh brass screen which keeps sand from etching it. He can see his work at all times while blasting, as the inside of the box is lighted.

The sand placed in the bottom of the blaster is drawn up by the blast gun, which is really a water siphon. In changing this water siphon to a sand blast gun, the designers have worked up a jet that can stand the brunt of sand passing through the nozzle with very little wear, even though the sand travels under 60 or 70 pounds air pressure.

The box is kept free from dust by a suction fan. The suction to the fan passes through steel wool that screens out the coarse sand particles, which drop to the bottom of the blaster and are used over again.

After meters are blasted they are given a coat of clear lacquer which gives all meters a uniform finish. Bottoms are painted black.



The Akron Sandblaster

*Contributed by W. R. La Due, Superintendent, Bureau of Water and Sewerage, Akron, Ohio.

ORIFICE TABLE FOR DETERMINING WATER FLOW

Compiled by the Engineering Department of Layne and Bowler, Inc., from original calibrations made in Hydraulic Laboratories at Purdue University.

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	10 in. Pipe	
5	100	76	145	140	280	220	380	320			5
5.5	104	79	153	145	293	230	394	333			5.5
6	108	82	160	150	305	240	408	345			6
6.5	111	85	167	155	316	250	421	358			6.5
7	115	88	172	160	328	260	433	370			7
7.5	119	91	179	165	339	270	446	383			7.5
8	122	94	185	170	350	280	458	395	600	935	8
8.5	125	96	190	175	361	289	471	408	617	963	8.5
9	128	99	195	180	372	298	483	420	633	992	9
9.5	130	102	200	185	383	307	495	433	650	1016	9.5
10	133	104	205	190	393	316	508	445	666	1040	10
10.5	137	107	210	195	402	324	521	458	682	1060	10.5
11	140	109	215	200	412	330	533	470	698	1080	11
11.5	143	111	220	204	421	338	545	480	713	1100	11.5
12	146	114	225	208	430	346	556	490	728	1120	12
12.5	149	116	230	212	439	354	567	500	743	1139	12.5
13	151	118	234	216	448	362	578	510	757	1158	13
13.5	154	121	239	219	457	369	589	520	771	1176	13.5
14	157	123	243	224	465	376	599	530	785	1194	14
14.5	159	126	247	227	473	383	609	540	799	1212	14.5
15	162	128	250	231	480	390	618	550	812	1230	15
15.5	164	130	254	234	488	396	627	559	825	1248	15.5
16	167	132	257	238	495	402	636	568	838	1266	16
16.5	170	134	261	241	503	408	645	577	851	1284	16.5
17	172	136	264	245	510	414	654	586	863	1302	17
17.5	175	138	268	249	517	420	663	595	875	1319	17.5
18	178	140	271	252	524	426	672	604	887	1336	18
18.5	180	142	275	256	530	432	681	612	899	1353	18.5
19	183	144	278	259	536	438	690	620	910	1370	19
19.5	185	146	282	263	542	444	699	628	922	1387	19.5
20	187	148	285	266	548	449	708	636	933	1404	20
20.5	190	150	289	270	554	455	717	643	945	1421	20.5
21	192	152	292	273	560	460	726	650	956	1438	21
21.5	195	154	295	275	566	465	735	657	968	1455	21.5
22	197	156	299	279	572	470	744	664	979	1471	22
22.5	199	158	302	282	578	475	752	671	990	1486	22.5
23	201	160	305	285	584	479	760	678	1001	1500	23
23.5	203	162	307	288	590	484	768	685	1012	1515	23.5
24	205	164	310	291	596	488	776	692	1022	1529	24
24.5	207	165	314	294	602	492	784	699	1033	1543	24.5
25	210	167	317	297	608	496	791	706	1043	1557	25
25.5	212	169	320	300	614	500	798	713	1059	1571	25.5
26	214	171	323	303	620	504	805	720	1064	1585	26
26.5	216	173	326	305	626	508	812	727	1074	1599	26.5
27	219	174	329	308	632	512	818	734	1084	1613	27
27.5	221	176	332	311	638	516	825	741	1094	1627	27.5
28	222	177	335	314	644	520	831	747	1104	1641	28
28.5	224	179	337	317	650	524	838	754	1114	1655	28.5
29	226	180	340	320	656	528	844	760	1124	1669	29
29.5	228	182	343	323	662	532	851	767	1134	1683	29.5
30	230	183	346	325	668	536	857	773	1143	1697	30
30.5	232	185	348	328	674	540	863	780	1153	1711	30.5
31	235	186	351	330	680	544	869	786	1162	1725	31
31.5	236	188	354	333	686	548	876	793	1172	1739	31.5
32	239	189	357	335	692	552	882	799	1181	1753	32
32.5	240	191	360	338	697	556	889	806	1191	1767	32.5
33	242	192	363	340	703	560	895	812	1200	1791	33
33.5	244	194	366	342	709	564	901	818	1209	1795	33.5
34	246	195	369	345	715	568	907	824	1218	1809	34
34.5	248	196	372	247	720	572	913	830	1227	1823	34.5
35	250	197	375	349	726	576	919	836	1235	1837	35
35.5	252	198	377	351	732	580	925	842	1243	1851	35.5
36	254	200	380	354	737	584	931	847	1251	1865	36

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	
36.5	256	201	383	356	743	588	937	852	1259	36.5
37	257	203	385	358	748	592	943	857	1266	37
37.5	259	204	388	360	754	596	949	862	1274	37.5
38	260	205	390	363	759	600	955	867	1281	38
38.5	262	206	393	365	765	604	961	872	1289	38.5
39	263	208	396	367	770	608	967	877	1295	39
39.5	265	209	398	369	776	612	974	882	1304	39.5
40	266	210	401	371	781	616	979	887	1311	40
40.5	267	211	403	373	786	620	985	891	1319	40.5
41	269	212	406	375	790	624	990	896	1326	41
41.5	271	213	408	378	795	628	996	901	1334	41.5
42	272	214	411	380	800	631	1001	906	1341	42
42.5	274	216	413	382	805	635	1007	910	1349	42.5
43	275	217	415	384	810	638	1012	915	1356	43
43.5	277	218	418	386	815	642	1018	920	1364	43.5
44	278	219	420	388	820	645	1023	925	1371	44
44.5	280	220	422	390	824	649	1029	929	1379	44.5
45	281	222	425	392	828	652	1034	934	1387	45
45.5	283	223	427	394	832	656	1040	939	1394	45.5
46	284	224	429	396	837	659	1045	944	1401	46
46.5	285	225	432	399	842	663	1051	948	1409	46.5
47	287	227	434	401	847	666	1056	953	1416	47
47.5	289	228	437	403	851	669	1062	958	1424	47.5
48	290	229	440	405	855	672	1067	963	1431	48
48.5	292	230	442	407	859	676	1073	967	1439	48.5
49	293	231	444	409	863	679	1078	972	1446	49
49.5	294	232	446	411	868	683	1084	977	1454	49.5
50	296	234	448	413	872	686	1089	982	1461	50
50.5	298	235	450	415	876	690	1095	986	1469	50.5
51	300	236	453	417	880	693	1100	991	1476	51
51.5	301	237	455	419	884	697	1105	996	1484	51.5
52	302	238	457	421	888	700	1110	1000	1491	52
52.5	303	239	459	423	892	704	1115	1005	1499	52.5
53	304	240	461	425	896	707	1120	1009	1506	53
53.5	305	241	463	427	900	711	1125	1014	1513	53.5
54	307	243	465	429	904	714	1130	1018	1520	54
54.5	309	244	467	431	908	718	1135	1023	1527	54.5
55	310	246	469	433	912	721	1140	1027	1534	55
55.5	311	247	471	435	915	725	1145	1032	1541	55.5
56	313	248	472	437	919	727	1150	1036	1548	56
56.5	314	249	474	439	923	730	1155	1040	1554	56.5
57	315	250	476	441	927	733	1160	1044	1560	57
57.5	316	251	478	443	930	736	1165	1046	1567	57.5
58	317	252	480	445	934	739	1170	1052	1574	58
58.5	319	253	482	447	938	742	1175	1056	1580	58.5
59	320	254	485	449	942	745	1180	1060	1586	59
59.5	321	256	487	451	945	748	1185	1064	1592	59.5
60	323	257	489	453	948	751	1190	1068	1598	60
60.5	324	258	491	455	951	754	1195	1072		60.5
61	325	259	492	457	955	757	1200	1076		61
61.5	326	261	494	459	958	760	1205	1080		61.5
62	328	262	496	461	961	763	1209	1084		62
62.5	329	263	498	463	964	766	1214	1088		62.5
63	330	264	500	465	968	769	1218	1092		63
63.5	331	265	502	467	971	772	1223	1096		63.5
64	333	266	504	469	974	775	1227	1099		64
64.5	334	267	507	471	977	778	1232	1103		64.5
65	335	268	509	472	981	781	1236	1106		65
65.5	336	269	511	474	984	784	1241	1110		65.5
66	338	271	513	475	988	787	1245	1113		66
67	340	273	517	479	995	793	1254	1120		67
68	343	275	520	483	1002	799	1263	1127		68
69	346	277	523	487	1009	805	1272	1134		69
70	349	280	525	491	1016	811	1280	1140		70

THE ANTHRACITE EQUIPMENT CORP.

101 Park Avenue
NEW YORK CITY, N. Y.

ANTHRAFILT — an Improved Filter Medium

Address sales and technical inquiries to

Palmer Filter Equipment Company, 822 E. 8th St., Erie, Penna.

Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

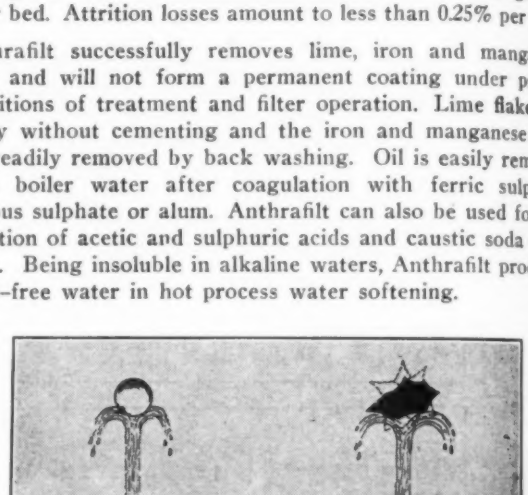
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effetixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sises of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

RENOVATION AND RUSTPROOFING APPLIED TO FILTER PLANTS

By PAUL WEIR

Asst. General Manager, Department of Water, Atlanta, Ga.

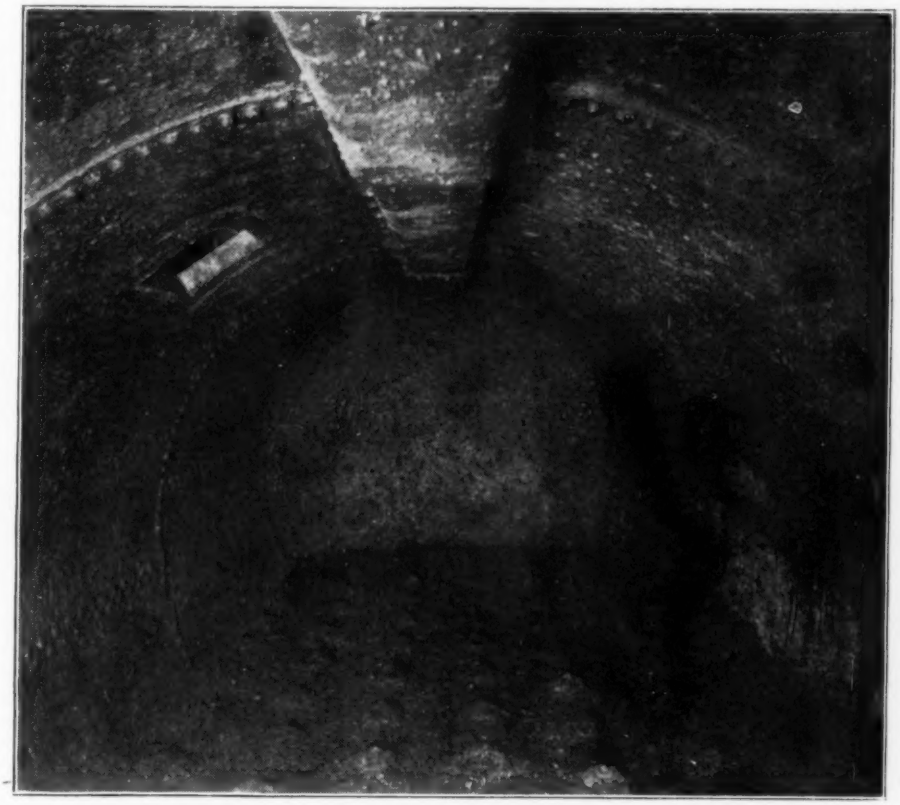
IN the Spring of 1942 the Atlanta Water Department entered upon a rustproofing and waterproofing project at two of its filter plants. The 21 M.G.D. reinforced concrete gravity plant is 20 years old, and the 18 M.G.D. steel tank pressure plant is 50 years old. "No Ox-Id" XX was used for both purposes very successfully.

The gravity plant consists of seven, 3 M.G.D. reinforced concrete filters. The renovation work included the waterproofing of approximately 35,000 sq. ft. of reinforced concrete surface and rustproofing 27,500 sq. ft. of 2½-in. diameter cast iron filter laterals, manifolds and 200 gate valves, varying in size from ¾-in. to 42-in.

The pressure plant consists of a battery of 36 horizontal steel filter tanks arranged in two rows. Each unit has the capacity of 500,000 gallons per day. The individual units are 8 feet in diameter, 20 feet in length and hold approximately 7,000 gallons of water. In addition to cleaning and rustproofing these metal filter tanks, 425 valves, ranging in size from 4 to 36 in. are being put in first-class condition. Since this plant was installed in 1893, it might normally be assumed to have served its useful life; but as a result of the rustproofing program, it is believed that the plant is now starting upon its second 50 years of service to the city.

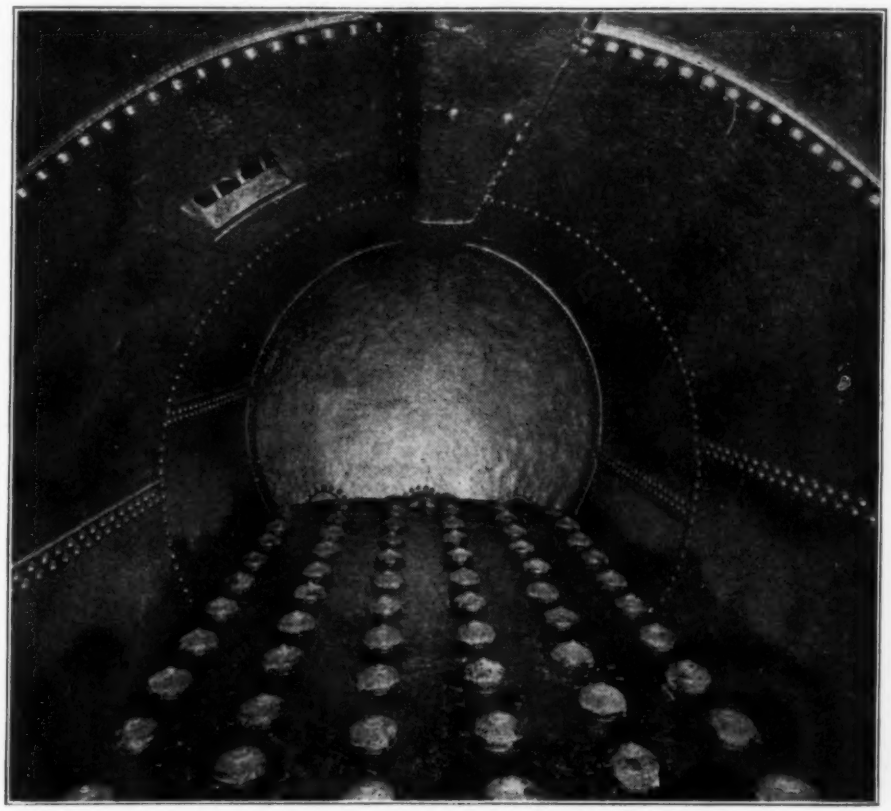
The Program and Procedure

Since the protective coating selected had already been determined upon from pre-

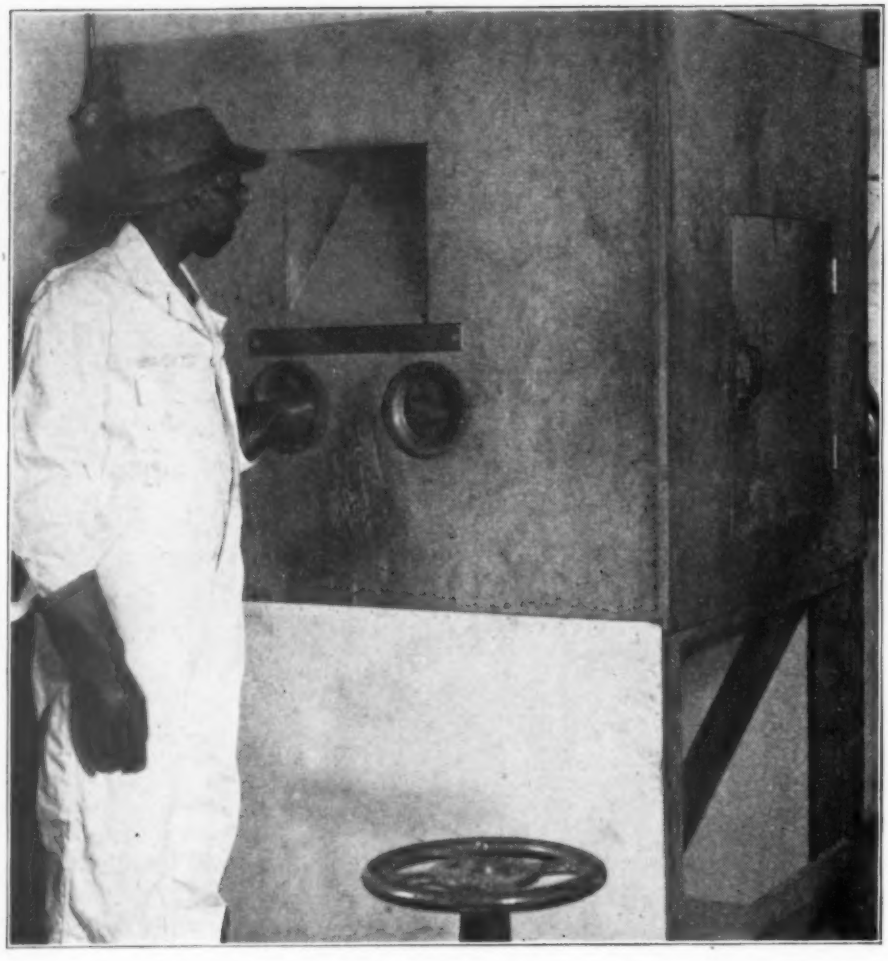


Section of One of the Steel Pressure Filters Before Cleaning and Rustproofing

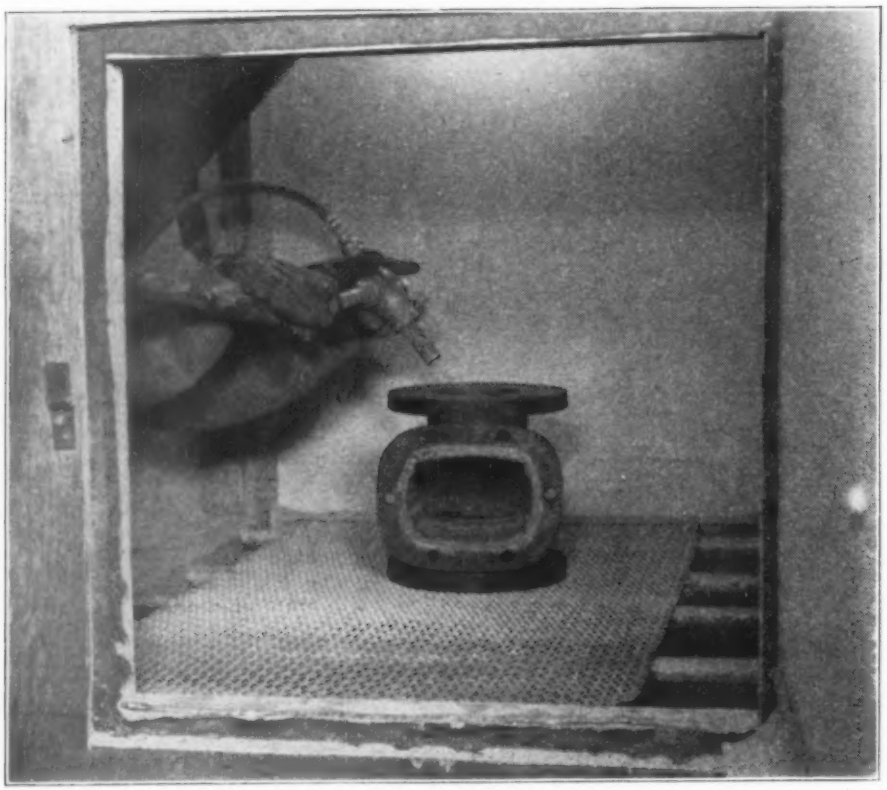
Cleaning the Interior Walls of a 50 Year Old Steel Pressure Filter by Use of the "Flame-Priming" Acetylene Torch.



Interior of Steel Pressure Filter "Flame Primed," Cleaned, Rustproofed and Ready for Service.



The Sand-Blast Cabinet and Operator at Work on a 50 Year Old Valve.



Sand-Blast Cabinet Interior
(Showing detail of home-built blast nozzle and hose used through rubber sleeved arm openings.)

vious information, tests and data, this article will be confined to a description of valve renovation, surface preparation and coating application procedures. It should be understood that choice of materials is a most important consideration and is worthy of thorough investigation. Our own investigation led to the use of "No-Ox-Id" coating, a highmelting paint wax containing rust inhibitors, which is effective both as a waterproofing and as a rustproofing agent. (See details in tabulation of materials and labor).

As Applied at the Gravity Filter Plant

The sand and gravel were removed from the filters by means of a hydraulic water ejector and discharged through a 4-in. pipe to a cleaning and regrading plant outside of the filter building.

The 2½-in. filter laterals were cleaned of rust adherent scale by sand blasting both inside and outside. They were then dipped into a vat of "No-Ox-Id XX" which was maintained at a uniform temperature of 250 degrees F. The dipping process required approximately two minutes. The laterals were next drained over the tank two minutes, and placed on the inspection rack to cool. After a final inspection, they were replaced in the filter bottom.

Treatment of Concrete Surfaces

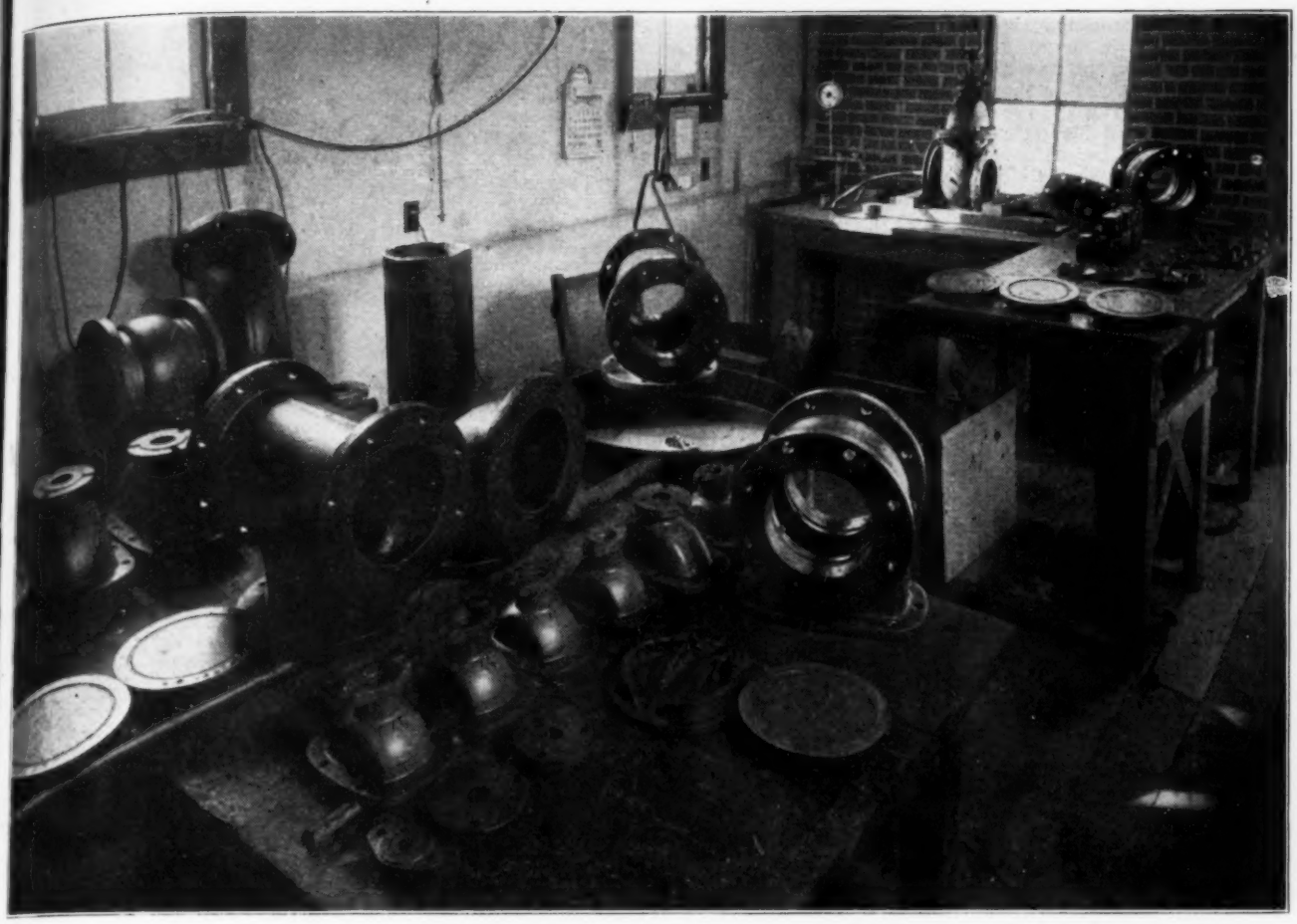
The concrete filter walls and bottoms were irregular and badly cavitated. No effort was made to bring the walls up to a uniform contour. They were carefully brushed by hand, cleaned of all loose particles, washed and dried and treated with a 1/32-in. coating of "No-Ox-Id XX." This material was applied by means of a specially heated pump applicator which insured a uniform thickness of material and absolute coverage. Thereafter, a non-carbonizing flame from a kerosene-burning torch (weed burner) was applied gently to this new surface in order that the finished wall might have a uniformly smooth coating. This final smoothing process with the torch also showed up any holidays or missed spots. These were touched up and smoothed by flaming with a blow-torch. In connection with use of the torch in the smoothing process, it is well to mention that the torch should be held at an angle to the surface and be moved in such a manner that the flame will strike the surface angularly. A slight sweeping effect to the movement tends to fill all pores better than perpendicular application of the flame.

Renovation of Hydraulic Valves

The hydraulic valves, which range in size from 8 to 42 in., were carefully cleaned by hand scrapes and power driven brushes. Necessary mechanical repairs were made, and the entire internal surface of the valve was coated with "No-Ox-Id A-Special." This was applied cold by hand, using a canvas glove and putty knife. The flame of a blow-torch was brought into contact with this material in order to obtain a uniformly smooth coating. Holidays and bare spots were detected by this method and touched up. New cup leathers were placed in all of the hydraulic piston chambers.

When all of the valves were finally replaced in service it was found necessary to reduce the original water pressure on the hydraulic system, because of the ease with which the reconditioned valves operated.

After all reconditioning work was completed, the gravel was replaced in the filters in layers, and the sand was returned by



"No-Ox-Id" Dipping Tank and Renovated Valve Parts

means of an hydraulic ejector. Each filter bed was carefully checked to ascertain its hydraulic characteristics, sand uniformity, and effective size. For sterilizing the filter beds approximately 3 pounds of chlorine gas were used per million gallon capacity. After a period of 48 hours each filter was checked bacteriologically and returned to service.

All work on the gravity filters was carried out by our local forces, who completed the job in approximately six months.

We have experienced no leakage in filter walls since this work was completed and the over-all efficiency of each filter has been materially improved. From the standpoint of rustproofing and waterproofing, they are better today than they were 20 years ago when the plant was new.

Work at the Pressure Filter Plant

The oldest of the steel pressure filter tanks were placed in service about a half-century ago, and while it is impossible to give a complete understanding of their condition, the pictures show rather clearly the pitted and corroded condition of the equipment.

After the sand and gravel were removed by an hydraulic ejector and conveyed by 4-in. pipe to a washing and grading plant outside the building, it was found that the interiors of these filters were badly tuberculated; and in many instances, the original ½-in. metal thickness had been reduced to ¼-in.

Surface Preparation by "Flame-Priming"

A number of different methods were used in attempting to remove the tenacious rust scale, the majority of which were unsuccessful. It was finally decided to remove all superficial and loose rust with billy shove's. An oxygen-acetylene flame-priming torch was used to dehydrate the remaining tenacious scale, which was readily removed by hand chisels and power driven wire brushes.

The flame-priming torch consists of a special ½x6-in. head, attached to a regular oxygen-acetylene handle, operated by means of a quick opening valve. It was furnished by the Linde Air Products Company. This equipment generated a temperature of approximately 6,200 degrees F. on the surface of the iron rust. Care was exercised not to overheat the area of the metal adjacent to the rivets. A 1200 cu. ft. per minute exhaust fan furnished fresh air in the tank through a second manhole.

After the interior of the filters was cleaned of all rust scale, the surface of the metal was heated to about 100° F. by a large natural gas torch. This was done to free the surface of the metal from moisture of condensation. It should be emphasized, that in using any torch for this purpose, care must always be exercised to maintain an oxidizing flame. If a reducing flame is used, carbon or smoke deposits on the surface of the metal might seriously limit effectiveness of the bond between the rustproofing coating and the metal. Immediately after the drying process, "No-Ox-Id XX" was applied to the surface of the metal by means of our temperature controlled coater, which is both heated and motor operated from a 110-volt A.C. electric circuit. —See picture.

A natural gas burner was used to smooth up this coating in order that holidays and bare spots might be detected. A second application of the coating material was then applied, which resulted in a total thickness of about 1/16-in. This was again flamed for final smoothness and the filter was ready to be recharged with gravel and sand.

Renovating Valves and Fittings

Valves in connection with the pressure-filters are all hand operated gate valves, with a history of from 30 to 50 years of continuous service. Most of these have been operated as throttling valves. The bronze faces on the gates, wedges and case rings, were badly worn and almost beyond repair. It was possible, however, to salvage bronze facings on about one valve in four. The other bronze faced gates, wedges and case rings were replaced with new parts by the Rensselaer Valve Co., the original manufacturer. It was possible to reclaim all other parts of the valves. They were returned to service when completely renovated.

All interior cast iron surfaces of the valves were badly tuberculated with rust and scale. We attempted to remove this material by means of hand scraping and power driven wire brushes. It required one person about eight hours to remove this scale by hand. It was impossible to properly clean corners and inaccessible areas, which predominated in the majority of the smaller valves reconditioned.

Development of a Sand Blasting Method

It was finally decided to remove the scale by means of sand blasting. This was accomplished by building a 4 ft. by 4 ft. by 8 ft. sand blasting cabinet, with a dust exhaust at the top. This was located on the filter operating floor. The photographs show in some detail the design and operation of this cabinet. The operator stands on the outside of the cabinet and operates the sand blast nozzle by reaching through

two rubber sleeved openings in the wall of the cabinet. A 14 in. by 20 in. glass window, set at an angle and protected by hardware cloth, is provided so that the operator can view the progress of the sand blasting which takes place entirely within the cabinet, without coming in contact with the obnoxious dust. Two 200-watt electric lights, arranged in the ceiling of the cabinet, afford ample illumination. The exhaust fan keeps the cabinet reasonably clear of dust so that vision is good. There is, however, sufficient etching impingement on the glass window to require its replacement occasionally. Valves and fittings up to 18 in. in size can be handled satisfactorily in this cabinet; but larger items are more conveniently handled by individual hand-cleaning methods.

In using the sand blasting cabinet, the casting to be cleaned is placed on a ¼-in. wire screen, supported on ¾-in. pipe the full width of the cabinet. A second reinforced 16-mesh screen constitutes the top of a steel hopper, which is installed 6 inches below the top ¼-in. screen on which the sand blast operation takes place.

About 300 pounds of sand is carried in the sand hopper, and this is drawn through a rubber hose from the bottom of the hopper to the sand blasting assembly by air pressure, then it is ejected out onto the metal surface to be cleaned. The ejected sand and rust particles are caught on the lower ¼-in. screen and the sand passes through the final 16 mesh screen, from whence it is returned to the sand hopper for recirculation to the air blast nozzle.

The ejector nozzle is also a home-made arrangement and consists of a ½-in. Y-lateral, or McDaniel suction tee, one leg of which is connected to the ¾-in. sand suction line, the second is reduced to ⅛-in. and receives the air line. The sand and air are ejected through the third ½-in. opening, into which is fitted a ½ by 3-in. nipple. Air pressure is maintained at approximately 90 pounds. Approximately 300 pounds of sand is used and re-circulated through the blasting system every hour.

While on the subject of sand, it should be pointed out that the character of sand is an important item in satisfactory sand blasting operation. The sand must be maintained in an absolutely dry condition, and a good grade of clean, sharp, silica sand must be provided in the first place.

The cast iron fittings are cleaned down to the bare gray iron in a surprisingly short time. It was soon discovered that the sand blasting would seriously cut all bronze surfaces and that some method of protecting them was essential. Knowing that "No-Ox-Id XX" would resist sand blasting, a heavy coating was painted on these surfaces and the entire fitting was then cleaned with the sand blast without damage to the bronze areas. The fact that the rustproof coating selected resists sand blasting is another evidence that it will give long resistance to normal wear, when applied to the interior surfaces of the filters.

After the valves were sand blasted, all parts were cleaned of silica dust by hand wiping with clean rags and brushes. The parts were then dipped into a 50-gallon steel dipping tank of "No-Ox-Id XX," which was heated to 180 degrees F. by means of a 6-in. diameter household natural gas burner—see picture.

It is important to point out that no water, air, or steam should be applied to the metal surfaces after they are cleaned and ready for coating. If either water, steam, or air were used for removing adherent dust particles after sand blasting, the adherent moisture would result in initial oxidation of the surfaces and would prevent proper adherence of the coating. This observation is quite contrary to the opinion held by some engineers with whom we discussed the problem before establishing our procedure.

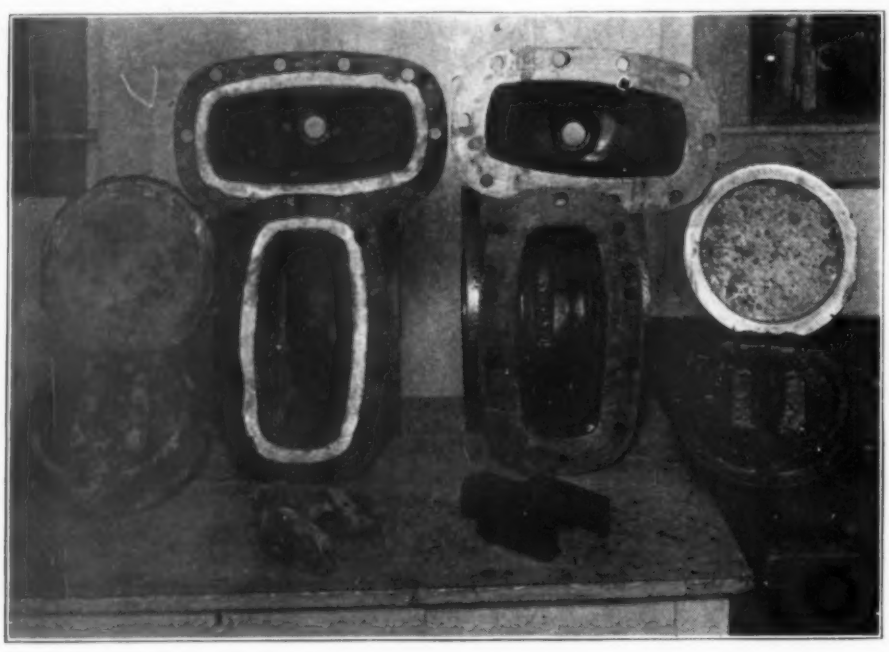
It was found necessary to maintain a uniform temperature of the "No-Ox-Id XX" in the dipping vat at 180 degrees F. This temperature resulted in a uniform protective coating. The time of dipping varies from two minutes to five minutes, depending upon the size of the casting. A small electrically operated hoist was used in the dipping process, and all fittings were allowed to remain suspended over the dipping vat approximately two minutes, after which they were placed on the inspection rack to dry and cool for final checking. All usable portions of the valves were then placed on the assembly table where the valve was reassembled and tested hydraulically at 25 to 100 pounds to insure proper operation.

Development of this procedure required many months of study and experimentation. The final results, however, are gratifying and permit us to further utilize an 18 mgd. filter plant which has already served the city for 50 years.

General Data on Quantities

	Man Hours Cleaning	Man Hours Coating	Man Hours Repairing	Thickness of Coating	Pounds Coating Material*
Metal filter tanks (per 1,000 sq. ft.)	80	36	..	1/16 in.	107
Concrete walls (per 1,000 sq. ft.)	58	20	..	1/32 in.	75
24 in. hydraulic valves (per unit)	11	1	4	1/32 in.	2
Miscellaneous valves and fittings 8 in. to 18 in. (per unit)	4	½	¾	1/32 in.	1½

*For all but the hydraulic valves the material used was "No-Ox-Id XX"; for the hydraulic valves "No-Ox-Id A-Special" was used.



Fifty Year Old 8-Inch Gate Valves Before and After Renovation and Rustproofing.

The Universal Hot Coater
(For application of viscous coatings.)

Materials and Equipment

For the benefit of those interested the following listing of materials and equipment utilized is given.

Coating Materials:
"No-Ox-Id" — Waterproofing and rustproofing compound.
"No-Ox-Id XX" — A high melting point wax with rust inhibitor. Melting point 155 degrees F. Will not become brittle at 40 degrees below zero. Used for both rustproofing and waterproofing.
"No-Ox-Id A-Special"—For rustproofing Hand application cold. Melting point 130 degrees F. Use for rustproofing.
(These coatings were supplied by The Dearborn Chemical Co. of Chicago.)

Cleaning Material:
Clean, sharp, dry, silica sand, passing 16 mesh screen.

Coating and Cleaning Equipment:
Steel Filter Tanks and Valves:
2½x7¼ in. Osborn Master Wheel wire scratch brushes.
6 in. diameter Osborn air power brush.
3 in. Red Devil wall scrapes.
1 Linde W-26 ox-weld acetylene flame priming torch and equipment.
1 Ilg Electric 400 cfm. exhaust fan.
1 Westinghouse Electric 2,000 cfm. exhaust fan.
1 Homelite gas motor, 2,000 cfm. exhaust fan.
1 Buffalo Forge Electric 1,200 cfm. exhaust fan (sand blast cabinet.)

Material Application Equipment:
5 gallon capacity kerosene burning torch.
1 ½ in. natural gas-air burning torch.
1 gallon capacity Universal Electric hot material coater.

Miscellaneous Material:
1 25 H.P., 115 cu. ft. Gardner-Denver air compressor.
1 5 H.P., 25 cu. ft. Curtis air compressor, portable.

F. B. LEOPOLD CO., INC.

Water Purification and Sewage Plant Equipment

422 First Ave. **Pittsburgh 19, Pa.**

Standard Filter Block

THE LEOPOLD
Filter Bottom

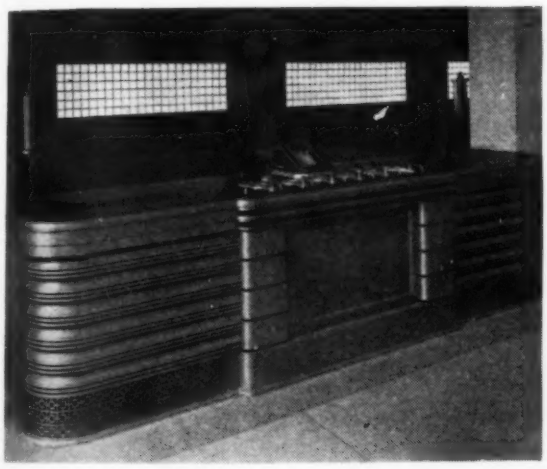
Non-Corrosive — Permanent

The Compound Duplex Filter Bottom is now produced from de-aired fire clay, vitrified and salt glazed.

The Leopold Filter Bottom cannot be compared with any other type of filter under-drain system as it is entirely different and eliminates all the difficulties experienced with other types. Each block is a separate collecting and distributing unit of 2 sq. ft. of filter area and assures a positive and equal collection of filtered water and distribution of wash water.

The large gravel bed is eliminated, thus removing the source of most filter troubles.

The Low Loss of Head through this system (less than 1.50 ft.) at the normal back wash rate, reduces pipe and valve sizes, making possible a great economy in piping design.



Filter Operating Table

Hydraulic Control Tables (operating tables) are master units for centralized control of hydraulic valves.

Leopold operating tables meet all requirements and are furnished in any size, combination or style desired.

Marble, asbestos, slate or metal cabinets, separate manifold headers, lubricated four-way valves, operating plates and levers and separate dial type valve opening indicators.

Designed for artistic effect, durability, long life, easy operation, and a minimum of attention.

DRY CHEMICAL FEEDERS

Leopold X-L type dry chemical feeders are of the volumetric type. Where quality, accuracy and long life is desired these feeders have long been the standard.

Manufactured in six standard sizes ranging in capacity from .5 to 1500 lbs. per hour based on alum.

For feeding alum, hydrated lime, soda ash, carbon or other dry materials.

Dry Chemical Feeder

STUART-BRUMLEY CORP.

516 NORTH CHARLES BALTIMORE 1, MARYLAND

ACTIVATED ALUM—BLACKALUM

The Best Coagulants for Your Needs

BLACKALUM is a powerful deodorizing and decolorizing coagulant. It contains powdered activated carbon. Alumina content over 17%. It provides maximum economy with greatest efficiency.

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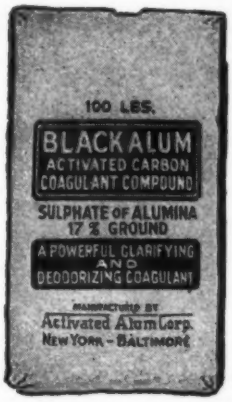

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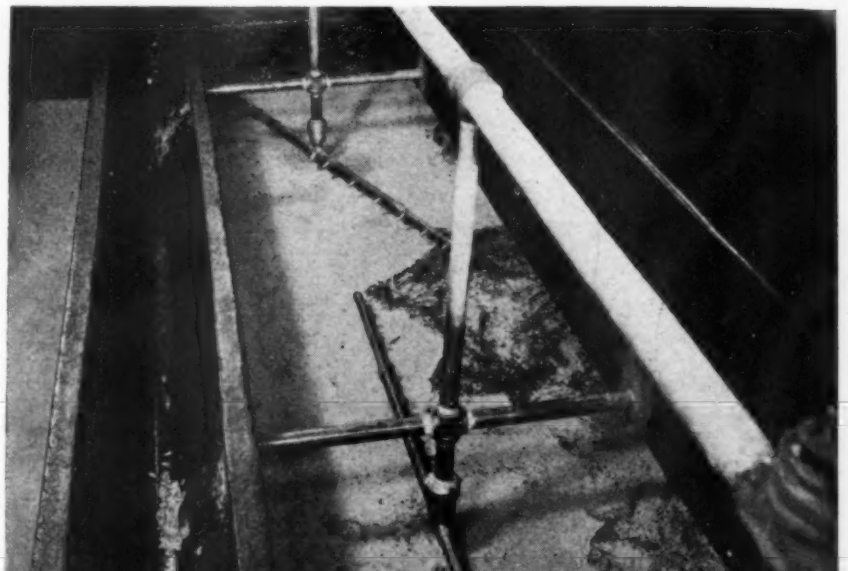

Palmer Filter Bed Agitators installed between concrete wash water troughs.

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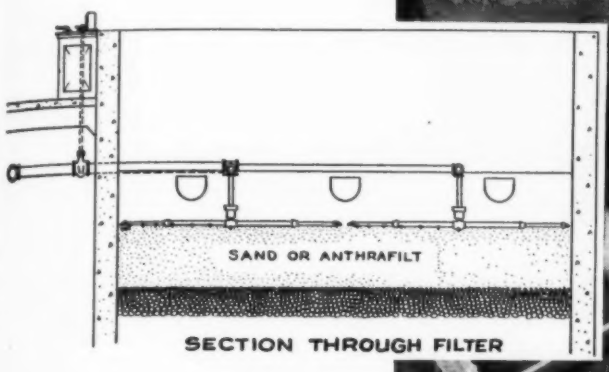

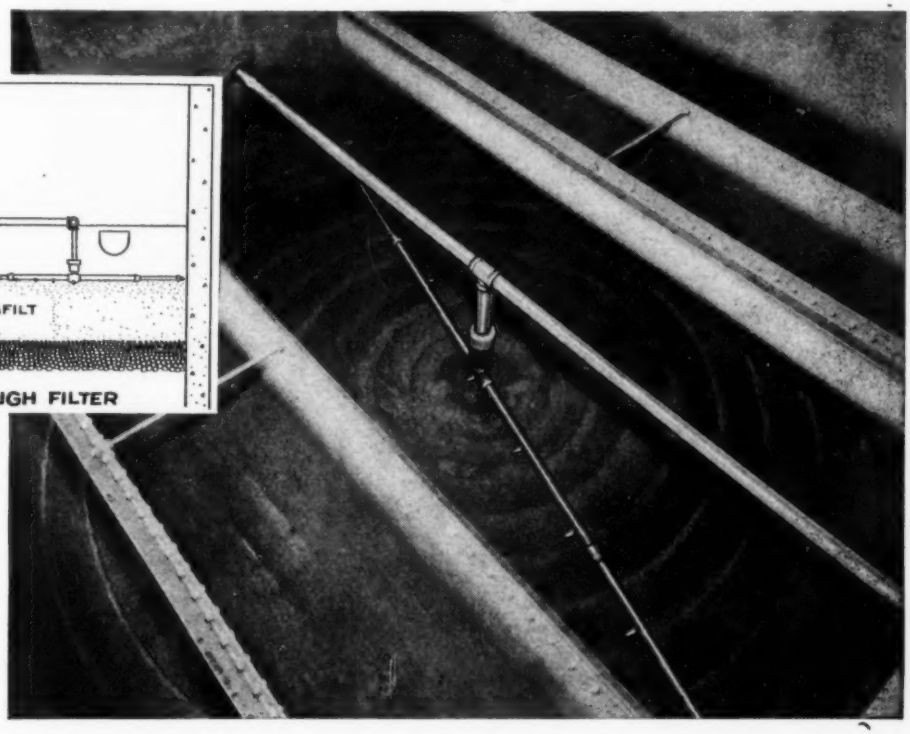

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CLEANING FILTERS WITH SULPHUR DIOXIDE

By J. G. PATRICK

Chemist, West Virginia Pulp & Paper Co., Luke, Md.

SAND grains of rapid sand filters frequently become coated with mud, biological slime, manganese, organic matter, iron, floc particles, or a combination of two or more of these film-building materials. When sand grains become thus coated the filter suffers loss of efficiency; mud balls and hard-spots appear, wash water requirements go up. The "schmutchdecke" era is of the past, and it has become well established that the "clean filter is the best filter." Several methods have been employed to loosen the coatings from filter-sand grains sufficiently to allow prevailing washing rates to remove them.

Caustic soda and chlorine, so effective in many cases, has been found of little value in loosening coatings made up in good part of manganese and iron oxides. Then the idea of utilizing an effective reducing material was considered. In looking for the reducing agent most simple to apply and least costly, the possibilities of sulphur doxide gas came to mind. The scheme proved simple and effective.

This paper tells of some of the experiences with the sulphurous acid method of sand cleansing in four filter plants. So successful has been the scheme that the writer has, for protective reasons, taken out U. S. Patent 2,069,621, covering "A Method of Cleaning Sand Filter and Appurtenances." This patent has been assigned to West Virginia Pulp & Paper Co. and its industrial chemical sales division.

Part I—Early Experiences at Luke, Md.

The process was developed at the 12 m.g.d. filtration plant of the West Virginia Pulp & Paper Co. operated under the writer's supervision.

The raw water is heavily contaminated with acid coal mine wastes contributing the useful but, at the same time, troublesome iron and manganese. Caustic soda, and alum to supplement the iron and aluminum salts in the raw water, are employed as the coagulating chemicals. Activated carbon is added to the raw water to assist in clarification. The iron content of the raw water averages 1.00 p.p.m. and is reduced to 0.17 p.p.m. by treatment. The manganese is less affected, being decreased only from 0.30 to 0.26 p.p.m. because of partial oxidation.

Early Cleaning Methods

After two years of service, attempts were made to clean the sand beds by treatment with a 2 per cent solution of caustic soda followed by stirring the sand by an air-lance. The sand was only partially cleaned. Total cost, including all incidentals, was $37.50 per filter of 154 cubic yards. Other efforts were made to clean the under-drains and filter bed by chlorine applications to the wash water, but this was only partially successful. Mechanical treatment was applied to break up the mudballs.

Sulphur Dioxide Tried

Sulphur dioxide had already proved successful in removing manganese deposits from the water mains in the mill. These mains were found to be heavily coated with the undesired hydrated manganese dioxide, which broke away to produce dark and smudgy specks that spoiled many tons of high grade white paper. A 0.2 per cent solution of SO_2 water (sulphurous acid), allowed to stand in the mains 6 hours, reduced and removed the manganese effectively.

Laboratory tests were first made by treating the filter sand with SO_2 water of various strengths. These tests showed a concentration of 3.0 per cent SO_2 in the water cleaned the sand to its original white, sharp grained condition.

Filter Bed Treated

The SO_2 treatment was then tried on a large scale with a filter bed. Preliminary to introducing the SO_2 the filter was prepared as follows:

(1) Filter thoroughly washed, to reduce gas consumption by loose material.

(2) Water drawn down through sand into gravel.

(3) Main effluent header and wash water valve closed.

(4) All small pipe connections across the Venturi and other meters closed.

(5) A cylinder of liquid SO_2 (similar to chlorine cylinders) was then attached to the effluent header by a brass pipe and standard chlorine tank connections and the SO_2 added as a gas. A heat evaporator was necessary to hasten the exit of the gas, and even that required a few hours to empty a tank. (In later applications the cylinder was inverted and 150 pounds of liquid SO_2 could be drawn off in 10 minutes, if desired.)

(6) As the liquid SO_2 was applied, the wash water valve was opened a little, water permitted to enter and force the sulphurous acid into the under-drains and up through the gravel and sand to a one-foot depth above it.

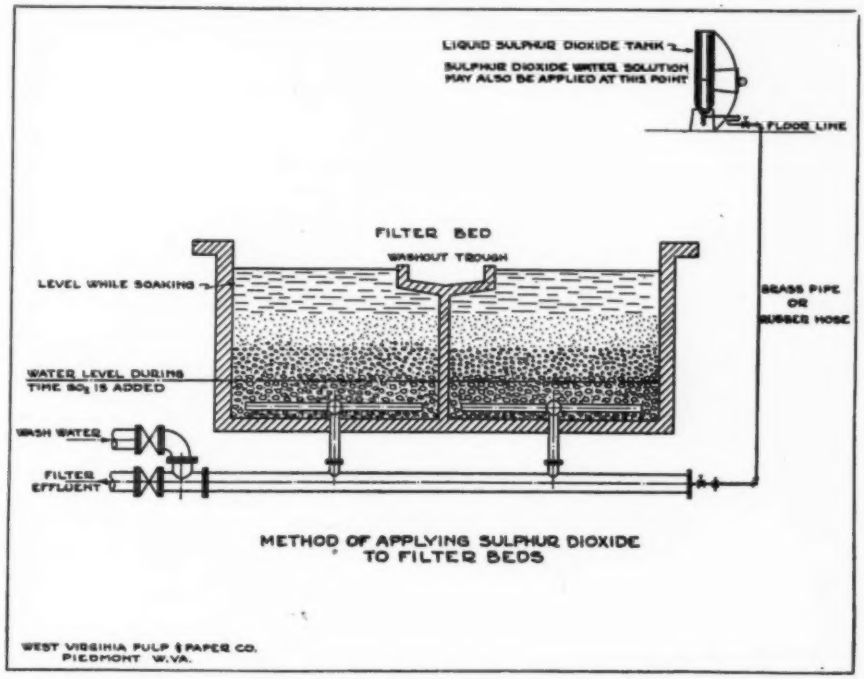
(7) After standing the required time the filter was given at least three back-washings.

Following the gas treatment the first washings were dark gray, changing to a light yellow. An analysis of the early material proved it was chiefly iron-aluminum floc discolored with some manganese dioxide and activated carbon. The yellowish substance was iron and manganese in solution.

The filters were so improved in efficiency and capacity, other treatments were given as conditions warranted.

Pertinent data giving the strength of solution, cost, and results obtained in treating three different 3 mil. gal. filter units (154 cubic yards of sand each) are given in Table I.

Since most of the coating was removed from sand, gravel and pipes the concentration of the solution for future treatment may be diminished and the interval between treatments extended to maintain practically clean surfaces.


LIQUID SULPHUR DIOXIDE TANK
SULPHUR DIOXIDE WATER SOLUTION MAY ALSO BE APPLIED AT THIS POINT
FLOOR LINE
FILTER BED
WASHOUT TROUGH
LEVEL WHILE SOAKING
BRASS PIPE OR RUBBER HOSE
WATER LEVEL DURING TIME SO_2 IS ADDED
WASH WATER
FILTER EFFLUENT
METHOD OF APPLYING SULPHUR DIOXIDE TO FILTER BEDS
WEST VIRGINIA PULP & PAPER CO. PIEDMONT W.VA.

Sketch Depicting Method of Applying Sulphur Dioxide to Cleanse Filter Beds

The quantity of SO_2 used was less than the amount shown by the laboratory tests; only enough to make a weak acid solution which is quickly spent, and likewise harmless to metal surfaces.

A dosage concentration of 0.3 per cent SO_2 appears to be rather effective without being corrosive at Luke. At this concentration, 150 pounds of SO_2 makes 6,000 gallons of sulphurous acid to fill the voids in the gravel and sand bed.

Mechanical agitation or raking the bed during treatment hastens the action. Naturally the longer the soaking period, within limits, the cleaner the sand becomes.

Results of Treatment

1. On the hard and over-capacity draughts there was no floc or dirt drawn through the filter bed.

2. Mud balls disintegrated.
3. The wash-water was more uniformly distributed throughout the sand bed.
4. Sand was lighter in color, having lost much of its coating; its buoyancy, too, had decreased.
5. Filter runs were extended 25 per cent in time between washings.

Advantages of the Method

1. Liquid SO_2 is easily obtained in convenient portable cylinders at a reasonable cost. Usually the commercial grade can be purchased at 10 to 12 cents per pound.
2. The application is simple with most filters. The cylinder may be connected to brass pipe by means of the standard flexible tubing and the adapters used with chlorine cylinders. (Rubber tubing, with brass union connections, may be used in place of pipes.) The average cylinder can be emptied as liquid within 10 minutes. (See sketch.)
3. Labor cost is small, requiring only a few man-hours to wash the filter preparatory to, and after treatment, and connect piping—a one-man job.
4. The SO_2 reacts not only with the manganese but also with the iron and other matter present. The sulphurous acid kills bacteria and plankton, disintegrates mud balls, and opens closed ports in the collector pipes. It reaches into inaccessible parts of the filter.
5. The SO_2 is less dangerous to handle than many other aggressive chemicals, especially sulphuric acid, sodium hydroxide, etc.
6. The removal of the sand, as with the ejector method, is unnecessary.

Preparations for Using SO_2

These tests demonstrated that sulphur dioxide gas must be respected and handled with reasonable caution.

All pipe connections must be kept tight. The gas is irritatingly unpleasant. A gas mask equipped with an "acid" gas canister is good protection to have at hand in case of an escape of the gas in a poorly ventilated room.

The liquid striking a moist skin may cause a "frozen-burn" from the resulting quick evaporation.

Comments

It is believed the sulphur dioxide solution (sulphurous acid) cleans the pipe interiors, the gravel, and the sand in the following manner. The coating existing mostly of iron hydroxide, hydrated manganese dioxide, silica, calcium and magnesium, alumina and organic matter, is acted upon by the sulphurous acid which reduces the manganese to the soluble manganous salts and the ferric iron to ferrous iron at least in part. The oxidation continuing, sulphuric acid is formed to some extent. The acid dissolves or loosens the incrustants, breaks apart agglomerations, scours the gravel, and unplugs collector pipe orifices that may be partially closed.

It is generally more economical to apply small doses of SO_2 at frequent intervals, since so little labor is required, thus removing a small portion of the coating each time, than to use a strong dose at longer intervals to get rid of a greater amount of the coating at one treatment. With the weaker solution, risk of corrosive attack on metal parts is far less.

It is our belief that the sulphur dioxide method of treating filters is the answer to the problem of loosening sand coatings for easy removal. For removing the calcium carbonate coating from filters in water softening plants, the scheme is not recommended, however. This because of the dangers of cementation of grains, caused by conversion of the calcium carbonate to calcium sulphite and, possibly, some sulphate where oxidizing compounds (iron and manganese) are present.

[Calcium carbonate can most effectively be removed by acid or chlorine water to form soluble chlorides.—Ed.]

Part II—A Demonstration at Baltimore, Md.

A demonstration was arranged with Mr. James W. Armstrong, Filtration Engineer, Baltimore, Md., to study the merits of the sulphur-dioxide process.

The raw water at this plant is from the Gunpowder River, where several billion gallons are impounded in Loch Raven reservoir. It contains an average of 0.5 p.p.m. iron (Fe); 0.2 p.p.m. aluminum (Al); and 0.27 p.p.m. manganese (Mn); and 38.0 p.p.m. alkalinity. Frequently the manganese content runs so high as to necessitate the use of lime and iron to precipitate it, with the iron, ahead of the filters.

The Filter

The filter, of 4 m.g.d. capacity, has a sand surface of 1,440 square feet, there being 18 in. sand depth and 18 in. of graduated gravel with a volume of 160 cubic yards. Voids are calculated at 40 per cent = 1,728 cubic feet, or 108,000 lbs. of water to fill the void spaces.

Sand is usually cleaned by an ejector-washer about every two years, requiring four men, at an approximate cost of $50 per filter. The gravel is dug out and run through a revolving grading screen, aided by hard jets of water. Much time is required to replace the gravel in the separate layers of the proper size.

Before the SO_2 treatment the sand had a deep brownish-black color and was sticky enough to be moulded wet. Several fair-sized mud balls and ridges were prominent. The gravel, as checked in an untreated filter bed (No. 14), had a pasty black coating about ⅛ inch thick. There was a thin coating of mud on top of the sand bed, and in some sections this mud had penetrated several inches into the sand. The concrete walls and troughs were coated with a dark slime.

The filter was given a thorough back-washing for 4½ minutes (151,000 gallons) preceding the treatment. The water rose unevenly through the sand, indicating several quiet or inactive collector pipe ports or hard spot interference.

SO_2 Application

The SO_2 supplied by the Virginia Smelting Co. was added as liquid. (See sketch.) Using the general procedure already described, the water level was lowered to near the bottom of the gravel (indicated in a gauge glass on outside of filter); the SO_2 was introduced; water then added slowly through the underdrains until the level was above the top of the sand. The soaking in this solution of sulphurous acid continued overnight. The filter was then backwashed a few times, and samples taken of the waste water from the top at the wash troughs and also underneath, from the rewash line. Examinations of the sand and the gravel were made and the effluent and wash water analyzed for iron and manganese after each treatment.

A connection was made with the cast-iron effluent header by means of a ⅜-inch brass nipple and valve. The SO_2 cylinder, on the operating floor above, was connected thereto with a flexible ⅜-inch rubber hose. An auxiliary valve, with union connection, was on the hose at the cylinder to aid in disconnecting the container and to prevent the escape of any SO_2 gas.

TABLE I

Application No.	SO_2 Lbs.	SO_2 Pct.	Soaking Period, Hours	Wash Water, Gals.	Cost: Labor	Cost: SO_2	Cost: Wash Water	Cost: Total	Cost: Per Cu. Yd.
(1)	100	0.100	5	200,000	$0.80	$10.00	$1.60	$12.40	$0.08
(2)	75	0.075	4	200,000	0.80	7.50	1.60	9.90	0.06
(3)	150	0.150	8	200,000	1.00	12.00	1 60	14.60	0.10

The quivering motion of the flexible hose, and the coating of frost on the brass valve and pipe at the effluent header, were good signs the liquid was flowing. The disappearance of the frost served as a good indicator that the cylinder was empty of liquid SO_2 and could be disconnected.

(Strong ammonium water serves well in detecting any leaks of SO_2, because vapors of ammonium sulfite (smoke) quickly form.)

Practically the total 1,950 pounds (13 by 150 lbs.) of SO_2 was added without any annoyance of escaping gas. The only perceptible odor was momentary during the occasional opening of a test valve for SO_2 water. The 1,950 pounds of liquid SO_2 (based on the 108,000 gallons in the 40 per cent voids in the sand) produced a 1.80 per cent solution. After dosing, water was introduced underneath to force the sulphurous acid formed up through and above the sand bed. Thus it stood during the overnight soaking period.

At the end of this time the filter was backwashed. Samples were collected from the wash troughs and from underneath the bed at the rewash or waste pipe, and other observations were made. The water samples were tested for pH, iron, manganese, and unspent (residual) sulfites.

Special Equipment

A convenient piece of apparatus, which facilitated and expedited the handling and the emptying of the SO_2 tanks, was a portable inversion stand supplied by the Virginia Smelting Com-

pany. This device consisted of a simple semi-circular rack made of one-inch angle iron. It was so balanced for rolling in one direction to pick up the full cylinder after clamping in place. A reverse roll inverted the cylinder to the vertical position, with the tank valve readily accessible for attaching the rubber hose. Two small wheels, midway of the arc, permitted easy wheeling in transportation, when the container was left in a horizontal position. It is truly a one-man, one-hand rack, allowing cylinders to be attached, moved around, or inverted with little effort. A 150-pound cylinder could be set into position and connected in 1½ minutes, emptied in 10 minutes, disconnected and removed in 1½ minutes—the total of 13 minutes being required for the complete cycle.

APPROXIMATE COST

Sulfur dioxide—1,950 lbs. at $.08	$156.00
Wash water—2,435,000 gals. at $8.00 M.G.	19.26
Labor—preparation—examination of bed	15.00
Total	$190.26
Total cost per cu. yd. of bed (160 yds.)	$1.19

After the third wash the sand and the gravel were examined by digging to the collector pipes. The sand was clean, bright in color, and the last two (larger) layers of gravel still showed good-sized areas of partly loosened or semi-dissolved typical black and pasty coating. With a longer soaking period or a higher velocity of wash water it is believed this coating would have been eliminated by the treatment, for it was easily washed off by one or two dips in quiet water. With the gravel in another filter (No. 14) untreated with SO_2, this pasty coating required considerable agitation or rubbing to remove it from the gravel. Further evidence that this coating was effectively loosened, and partially dissolved, was shown by the fact that the filter had to be drained to waste for several hours before it was sufficiently free of manganese content to warrant turning the water into the clear well.

Results from Treatment

Inasmuch as primary interest was in removing the coating on the sand and gravel, and this coating was composed chiefly of iron and manganese, these objectionables have been used as a criterion of cleaning in the following data. Results are expressed in pounds per ton (2,000 lb.) of the sand.

	Pounds per Ton—Iron	Pounds per Ton—Manganese
Sand—Before SO_2 Treatment—		
Top of bed	30.83	7.45
Bottom (next to gravel)	22.38	12.44
Sand—After SO_2 Treatment—		
Top of bed	.10	2.49
Bottom (next to gravel)	.08	1.99

Assuming that if the samples of wash water, containing the dissolved materials, were true representative composite samples, and based on the approximate two million gallons of wash water used in clearing the beds, there were removed in the backwash 410 lb. of iron and 1,892 lb. of manganese. With such a large unit, however, it was impossible to get truly representative dirty water samples.

The SO_2 treatment was effective in reducing the size of most mud balls and eliminating or disintegrating some entirely. The sand was cleaner and looser throughout, as shown by the surface motion during backwashing.

The dark color of the backwash water after the soaking, the floc it contained, the brightening of the sand, and the softening and the removal of the greater portion of the black and pasty coating on the gravel and the underdrains, are all evidence that the entire filter was materially cleaned. A few clay-like mud balls remained intact.

Part III—Cleaning the Batavia N. Y. Filters

At the municipal water filtration plant of Batavia, N. Y., an SO_2 cleaning demonstration was successfully made November 13-15, 1937.

Two filter beds were treated, one with a 2 per cent solution of sulphur dioxide (sulphurous acid) based on the weight of water in the filters; and another, partly cleaned with a one-half dose, or 1 per cent SO_2. Preliminary laboratory tests on small samples had determined that a 2 per cent SO_2 application would restore the sand to its original quartz whiteness. The contrast between the uncleaned and the cleaned sand was striking. The partly cleaned sand gave an intermediate gray-white color.

After demonstrating to Mr. H. M. Cook, Supt. of Water Works and Filtration, how easily the SO_2 could be applied, he treated the rest of the filter units himself with 1 per cent applications.

Condition of Filter Beds

The sand in these beds was not as dirty as some, although it bore a dark brown coating of sufficient thickness to cause the adhesion of sand grains to each other. There has been no trouble with the coating breaking off and clouding the effluent. The beds were last cleaned in 1930 when Leopold type filter-bottoms were installed. Mud balls were absent due probably to the hard hosing treatment which has been a practice after each backwash for some weeks. The condition of the gravel and the underdrain is not known as it has been some time since they were inspected.

SO_2 Dosage—Recirculation Tried

The usual procedure was employed in treating the Batavia filters. They were given a good backwash, drained through the effluent waste, then wash water introduced to bring the water level up into the gravel bed. The depth of this water was determined by a small pipe gage fastened to the effluent header. The liquid SO_2 was added from an inverted cylinder through the rubber hose and brass connections into a tap made between the valves and the filter manifold or underdrain header. After the addition of the SO_2 enough wash water was run in to bring the solution level to a few inches above the top of the sand bed. The SO_2 hose was then disconnected and a one-inch hose was attached to the top and connected to the suction side of a small centrifugal pump delivering 8 gallons per minute. The discharge from this pump was carried away by ordinary garden hose, the nozzle end of which was kept submerged under the water above the sand. Every 30 minutes this nozzle was moved to a new point on the sand bed to insure a positive action at all sections. This circulation accelerates the activity of the sulphurous acid and it was a marked improvement over the natural diffusion experienced at Luke, Md., and Baltimore. It is the first time that recirculation was tried and it is believed it would be especially advantageous not only to insure movement of the solution and sulphur dioxide economy, but also in breaking up mud balls and enlivening dead spots.

This recirculation continued for 24 hours, at the end of which time the sand under the 2 per cent solution had entirely lost its coating and had regained its original color. As mentioned above, the test with the 1 per cent solution did not remove all incrustants.

Within a few hours the supernatant liquid on top of the sand changed to a deep lemon color and some SO_2 odor came from this, but at the end of the soaking period there was no trace of SO_2. The filter was backwashed several times as follows:

Back Washing	Time	Gals.	Waste Water	pH
1st	9 min. (Stood 1 hr.)	30,000	Amber	6.0
2nd	7½ (Stood 1 hr.)	25,000	Light floc.	6.2
3d	7	23,000	Clear	6.3

The first backwash water was a deep amber color covered with several inches of foam. After the above three washings, the filter was put in operation with the effluent run to waste for about 5 hours, and when the pH reached 7.1 was put "on to the line." Measurement of the sand bed before and after treatment showed but little change in depth. That the sand was uniformly cleaned throughout the bed was shown by digging to a depth of two feet in several places. Twenty-four agar plates and fermentation tests on the filter effluent, after cleaning, gave negative results. This is more proof that the sulphurous acid has bactericidal and bleaching action as well as chemical action.

Part IV—Cleaning the Filter Beds of the Long Island Water Corporation, Valley Stream, L. I.

A fourth demonstration was made at the request of the Freeport Sulphur Company which has been studying new applications of sulphur compounds through a fellowship at New York University, New York City, under the supervision of Prof. L. V. Carpenter.

The sand was incrusted with a bright reddish iron oxide. These filter beds were a striking example of an unusual condition, since the water is heavily loaded with iron and manganese and the chief problem has been to remove these compounds.

One of the four 1.5 mgd. filters was treated with a 2 per cent solution of sulphur dioxide. This filter bed had recently been opened to examine and replace strainer head, and samples of the gravel and sand were obtained. The gravel bore a typical blackish-brown pasty coating about 1/16 in. thick of the hydrated manganese dioxide. As the sand was uniformly incrusted with ferric oxide, more on the order of a stain, this red oxide when dry in the sunlight caused the sand grains to resemble garnets. This coating furthermore is an advantage as it has a contact or catalytic action in iron removal. It is claimed that this iron incrustant once eliminated would reduce the efficacy of the sand as an iron remover, and it was estimated that several weeks

would be required to form a new coating. Apparently the coating has become constant since the effective size of the grains has increased only 0.08 mm. with 4½ years' continuous service.

Since the gravel was so heavily coated it is reasonable to think the interior of the effluent header and other lines carry similar coating.

Although the sand in some beds has been shifted by an ejector this is claimed to give little cleaning action. The sand was free and there was evidence of mud balls or effect on filter runs, etc. The filters are washed every 24 hours. It is reported that the interior of the distribution mains to the consumer are being steadily coated with a black deposit which occasionally breaks away and becomes apparent in the water. This further suggests that the manganese is being deposited within the mains. The raw water is from deep wells from 150 to 200 feet deep. A typical analysis of raw and filtered water is as follows:

	ppm. Raw	ppm. Filtered
Iron	2.0	0.10
Manganese	0.03	0.00
Hardness ($CaCO_3$)	21.0	25.00
Carbon dioxide	19.0	2.00
Alkalinity, M. O.	14.0	24.00
Color	5.0	0
Turbidity	5.0	0
Dissolved oxygen	...	6 g/1
pH	6.0	7.2

Treatment consists of aeration by an Aeromix unit, followed by the addition of 0.6 grains per gallon of lime for oxidation and precipitation of most of the iron during the 15-minute sedimentation preceding filtration. The effluent of the rapid sand filters is stored in open, slow sand filters through which the water is drawn from the bottom and pumped to the distribution mains, hence having double filtration.

SO_2 Treatment

For cleaning filter No. 3 the quantity of liquid SO_2 required for a 2 per cent solution was calculated as follows:

16 ft. x 22 ft. x 5 ft. bed	=	352 sq. ft. area = 1,760 cu. ft.
1,760 cu. ft. x 62.5 x 40% voids	=	44,000 lb. H_2O
To produce 2% solution	=	880 lb. SO_2
Pipes 1x10 in. + 1x12 in. x 16+16+11 = 32 cu. ft.	=	40 lb. SO_2
3 in. water above sand = 0.25 ft. x 352 = 88 cu. ft	=	110 lb. SO_2
Total		1,030 lb. SO_2

Actually used 1050 lb. SO_2 @ 9 cents pound = $94.50.
Total solution 6,180 gals.

The regular procedure was used, washing the filter thoroughly, draining it, then adding enough water to take up the SO_2 which was applied in stages, as noted below, to obviate high concentration of sulphurous acid in the header for any long period. The seven cylinders of liquid SO_2, 1,050 lb., were added without any leaks or other annoyances.

Recirculation, as described in the Batavia work, was employed during the 15 hours' soaking period, with a 9-gallons-per-minute pump which actually turned over the solution (theoretically) 1.3 times. The hose nozzle was kept submerged and moved at regular intervals over the surface at all times. A slight odor of SO_2 arose from the surface of the bed for the first hour and then disappeared. Within five minutes after the water had been raised to above the sand the solution had begun to turn red and at the end of the soaking period the color was a deep crimson or blood red, too dark to see through.

Back Washing

At 11 a.m., the next day the filter was backwashed as follows:

Wash	Time	Color of Solution	Wash Water, Gals.
1	10 min.	Blood red Stood 15 minutes	50,000
2	5 min.	Lemon yellow	25,000
	Apparently no change in deep red color of sand at 12" below surface. Stood 3 hrs. 10 min. pH 4.2.		
3	5 min.	Light lemon yellow	25,000

At 3:45 p.m. filter put in operation, effluent run to waste. pH 5.7.

At 9:00 p.m. filter put into service. Effluent pH 7.0.

A sample of the gravel was removed several days after the treatment and was found to be clean or free of the black manganese and iron coating.

The sand, however, remained little changed in appearance. Since this iron incrustant is an advantage in the water treatment it is well it retained its iron oxide coating.

Results

Sand Examination

Professor Carpenter and his associate, Mr. John Coates, found the following:

Sieve Analysis	Effective Size	Uniformity Coefficient
New sand	0.44	1.50
Before SO_2 treatment	0.52	1.56
After SO_2 treatment	0.485	1.59

The effective size changed by the treatment from 0.52 to 0.485, while the uniformity coefficient remained practically constant.

Further analysis showed the sand incrustants (Fe_2O_3) before cleaning were 6.9 per cent and 5.9 per cent after treatment. Calcium and magnesium were not found in the incrustants, but a small amount of manganese was present.

Analysis of water above sand after recirculation 15 hours* (Piedmont Laboratory):

	Gms./L.	ppm.	Lbs. in Filter Solution
Total solids	30.1	30,100	1,550
Volatile and organic matter	11.0	11,000	564
Silica (acid insol.)	0.9	900	47
Iron	5.9	5,900	310
Manganese	2.4	2,400	124
Calcium	2.1	2,100	108
Magnesium	1.4	1,400	72

(Ed. Note: Since original publication of this article the use of sulphur dioxide to clean filters has found favor in a number of other plants throughout the country, notably Louisville, Ky., Noonan, Ga., Tarrytown, N. Y., Passaic Valley, N. J., and Perth Amboy, N. J. among others.)

*Based on 6,180 gallons in filter, and assuming this was a representative sample.

PROPORTIONING CONCRETE

Proportions of Mixtures Cement	Sand	Stone	Material For One Cubic Yard Concrete — Gravel ¾" and under: Cement Bbls.	Sand Yards	Stone Yards	Stone 1" and under, dust screened out: Cement Bbls.	Sand Yards	Stone Yards	Stone 2½" and under, dust screened out: Cement Bbls.	Sand Yards	Stone Yards
1	2	3	1.54	.47	.73	1.70	.52	.77	1.73	.53	.79
1	2	4	1.34	.41	.81	1.46	.44	.89	1.48	.45	.90
1	2	5	1.17	.36	.89	1.27	.39	.97	1.29	.39	.98
1	2½	4	1.24	.47	.75	1.35	.52	.82	1.38	.53	.84
1	2½	5	1.10	.42	.83	1.19	.46	.91	1.21	.46	.92
1	2½	6	.98	.37	.89	1.07	.41	.97	1.07	.41	.98
1	3	5	1.03	.47	.78	1.11	.51	.85	1.14	.52	.87
1	3	6	.92	.42	.84	1.01	.46	.92	1.02	.47	.93
1	3	7	.84	.38	.89	.91	.42	.97	.92	.42	.98
1	4	6	.83	.51	.77	.90	.55	.82	.92	.56	.84
1	4	7	.77	.47	.81	.83	.51	.89	.84	.51	.90
1	4	8	.71	.43	.86	.77	.47	.93	.78	.48	.95
1	4	9	.65	.40	.89	.71	.43	.97	.73	.46	1.01

1 Bag of Cement ..... = 94 Lbs.
1 Bag of Cement ..... = 1 Cu. Ft.
4 Bags of Cement ..... = 1 Bbl.
1 Bbl. of Cement ..... = 400 lb. Gross, 376 lb. Net

PRACTICAL ASPECTS OF POROUS PLATE FILTER BOTTOMS

Based on Experiences at Larchmont, N. Y.

By HENRY T. HOTCHKISS, Supervising Chemist
Department of Water and Sewage, Larchmont, New York

IT IS obvious that in passing down through a filter bed, water goes from zone to zone of varying function. The sand-gravel interface has received notice in connection with both sand support and wash water distribution. Such functional analysis is necessary in order to understand the losses of effectiveness which may arise from disruption in any of these zones and so that corrective measures may be taken.

In an otherwise quite excellent outline[1] there is found a general disclaimer for faulty filter design in the following statement: *"Sometimes trouble occurs in a filter bed due to local displacement of gravel. It may be that some of the large gravel has been forced upward through the fine gravel, or the fine gravel may be ridged or mounded in places. Unless the causes for such conditions are understood, the general movement may be wrongly attributed to faulty design or construction of the filter bottom."*

This, the writer believes, should not be accepted as a dogmatic statement that filter design has been perfected or standardized, but rather as an admission that improvements are needed.

Again a statement[2] is made that *"Another drawback is that although we may say filters are poorly designed, we do not have good proof of the assertion.*

"Perhaps most of us believe we know a better filter design, yet no one has produced a filter bottom in which filter beds handling various types of water have all remained in good condition. Either the ideal design has not been found or there are certain inherent weaknesses which cannot be remedied by any design of the bottom. The latter is believed to be the reason."

This statement should spur on investigations seeking to perfect both design and operation.

Bed Surface the "Tell-Tale"

The surface layer gives some indication of the state of affairs in the zones below. Mounds and craters are generally symptoms of internal troubles. Smaller mudballs may be localized at or near the surface, but hard spots and cracks due to bed shrinkage result from dirty sand or upset gravel. Surface washing systems, when provided, give the operator a valuable tool for improving sand conditions. They cannot, however, be expected to correct deep bed disruptions. A clever operator, even without use of surface wash, can, by the use of rake and water jet, "iron out" these surface blemishes. This, however, does not correct the underlying flaws. These can only be cured by a major operation.

There is, unfortunately, no influence acting during the backwashing operation to restore, once disturbed gravel to its original graded position. This is so because those forces which move the gravel are all localized and due to high velocities created by various conditions over which the operator may or may not have control. Studies indicate that at times, when wash water is first introduced—and even when the rate-of-rise is still low—there is a tendency for the sand to expand *from the bottom* as the sand mass is lifted. Then a weakening takes place, at one or more points. Finally gravity prevails and the less dense fluid (sand-water mixture) gushes up through. The velocities of these vertical jets, coming from deep down, are of gravel moving magnitude. This may and does happen before a normal maximum rate-of-wash is reached. The fewer the points of breakthrough, the more violent is the local action. [Filter beds containing air removed from the water during filtration have been known to "blow-up" when cracking the wash valve with the net result of an inverted gravel bed and trouble.—Ed.]

In recent years, the importance of the sand-gravel junction has been more fully appreciated.[3] In this zone the wash water is finally distributed to the sand. The loss-of-head throughout the interface must be of constant magnitude if even velocity distribution is to be attained. Here, however, is the most unstable portion of the gravel, because the gravel approaches sand grain dimensions.

Why the Gravel Bed?

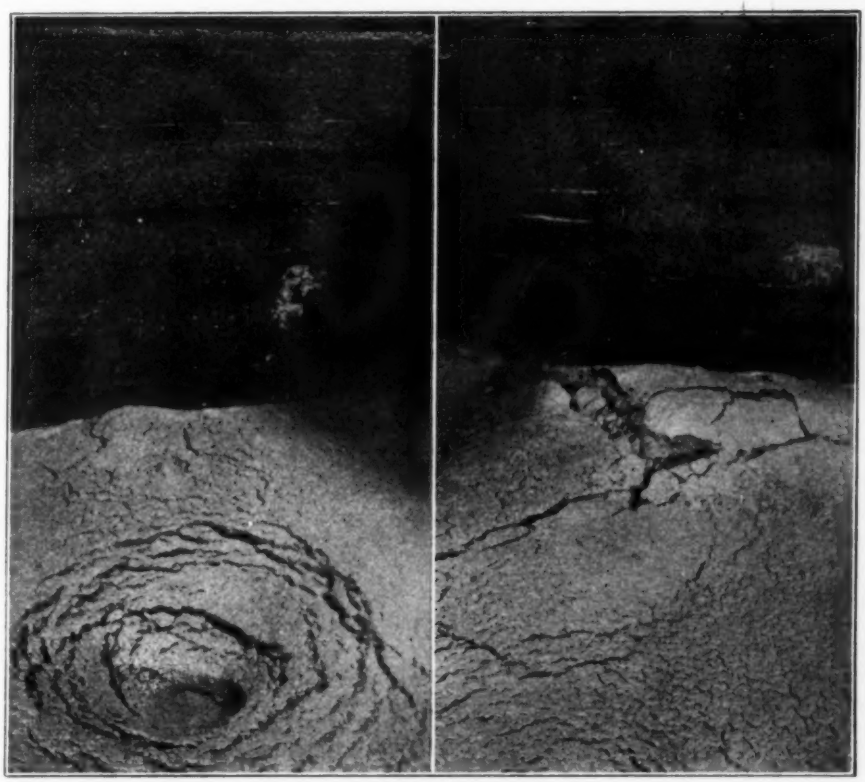
Sand of good quality and proper size is provided to act as a straining medium, primarily for removing the suspended matter present in the applied water. In rapid mechanical sand filters the action is physical in nature.

As for the gravel, it does not seem possible to build such a substantial case of necessity. As a matter of fact, from what has been outlined previously, the evidence indicates that a good case exists for eliminating gravel from filter design. This can be done if a method of supporting the sand and distributing the wash water can be provided. The proposals of H. N. Jenks[4] and especially the studies of Professor T. R. Camp have led to the production of manufactured porous plates for this purpose. Their use appears to be a cure for chronic filter illness due to deep bed gravel upheavals.

The Porous Plate Bottom

Any discussion of the merits of porous plates over conventional under-drain systems has been purposely omitted since this topic has already been given some attention.[5]

It must be admitted that there is the likelihood of fine grained

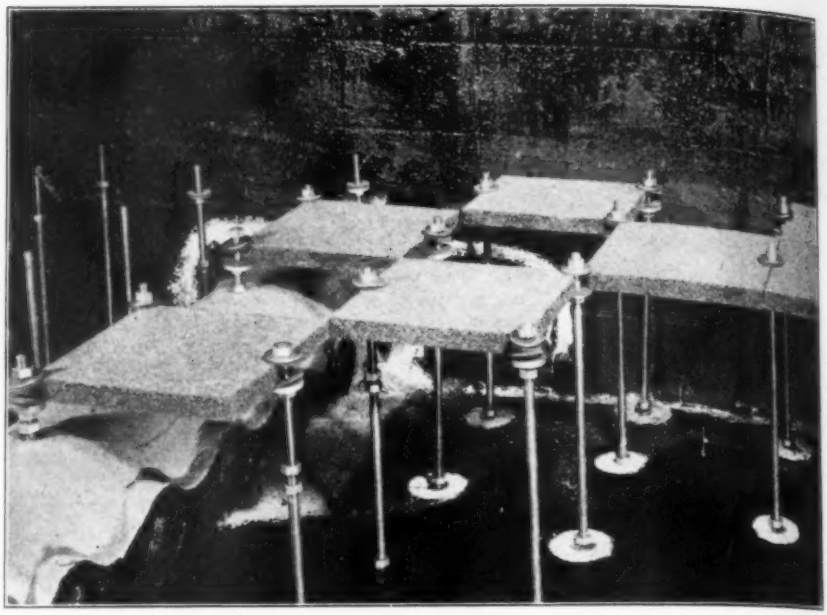


Some Cause for Concern

Filter Bed Conditions at Larchmont Which Aroused Our Interest in the Possibilities of Improved Design and Eventually the Installation of Porous Plate False Bottoms and Elimination of Trouble-making Gravel.

plate clogging; but because of the comparatively low initial head loss through the plates and because of the equalizing factor which exists as the less resistant pores become constricted, considerable leeway is provided before cleaning operations are required. Possibly, routine treatment of the plates with dilute acid at one or two year intervals will be found desirable. Certainly, the characteristics of the applied water should be scrutinized carefully if calcium carbonate or other deposition is probable, so that suitable provisions may be made for protecting the plates.

Since the advent of the porous plate filter bottom there has been a conservative desire to know, in advance, just what the life of the plates will be. There is no question concerning their mechanical strength. Nor is there doubt of their ability to withstand the chemicals normally present in water and sewage, or even acid solutions of considerable strength. The question raised is a matter of performance. Will clogging take place at a rate which will nullify their usefulness? Subsequqent to the provision of automatic rate-of-wash control it has been possible to secure comparative loss-of-head data.



Construction of Porous Plate Filter Bottoms at Larchmont, N. Y.
The Norton plates (12"x12") are installed with three point support, making for ease in levelling and alignment. The rods, washers and bolts are of "Everdur" bronze. The plates form a false bottom above the original manifold.

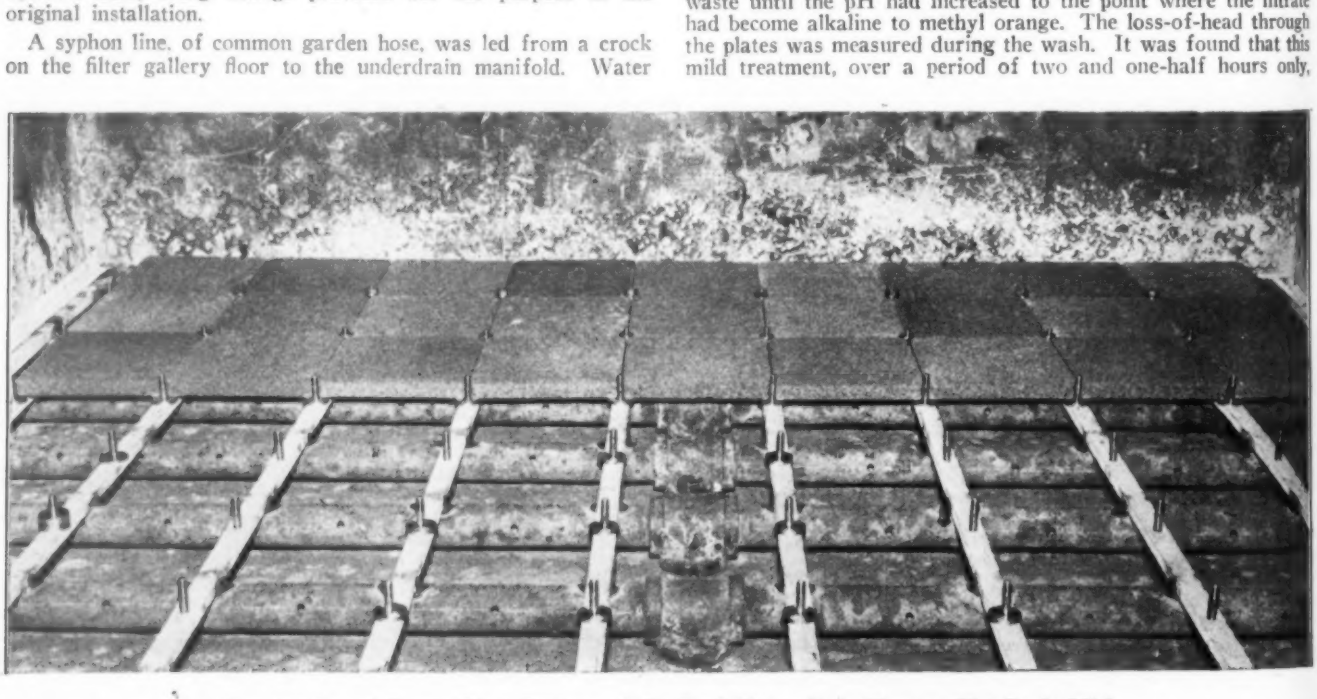
Larchmont Experiences

The original filter unit, equipped with a porous plate bottom and placed in service July, 1939, in our plant, as recounted in this magazine,[8] has been in continuous use. This was equipped with piezometer tubes just above and below the plates in order to follow any changes in the hydraulic characteristics of the plates. Readings taken indicate, as anticipated, an increase in loss-of-head. An intermediate interval was also observed when the loss decreased for a time. The net result by February 21, 1941, was a total head loss through the plates of 24 inches of water. This was with a wash rate of 16.1 gals. per sq. ft. per min. (approx. 26 inch rise per min.). This head loss is not considered high. New plates showed an initial loss of four inches of water under similar condition. The loss during filtering at design ratings continues very low.

In order to provide some indication of the effectiveness of rinsing the plates with dilute acid, the unit was cut out of service on February 21st. The following procedure was used to introduce sulfuric acid, using fittings provided for the purpose in the original installation.

A syphon line, of common garden hose, was led from a crock on the filter gallery floor to the underdrain manifold. Water flowed into the crock and to the filter bottom by way of the syphon at about five gallons per min. The 66° Be. technical sulfuric acid was run into the crock at a slow rate by means of a glass funnel so that within an hour's time 81 lbs. had been used. A solution of 1¾ per cent by weight, on the basis of the acid used, was thus made and provided about 300 gals. of dilute acid. The level of water in the filter, which had previously been drawn down just to the sand, rose slowly. The water flowing through the hose was permitted to force the acid slowly up through the plates and sand for an hour.

Thereafter, wash water was introduced at a slow rate for an additional half-hour, when the water level had reached to within a foot of the lip of the wash gutters. Then the wash was continued at normal rate, utilizing 30,000 gals. to sweep out the residual acid and loosened solid. Water was then filtered to waste until the pH had increased to the point where the filtrate had become alkaline to methyl orange. The loss-of-head through the plates was measured during the wash. It was found that this mild treatment, over a period of two and one-half hours only,



Construction of Power Plate Bottoms of the Ford Motor Co.'s Plant at Flat Rock, Mich.
The "Aloxite" 12"x12" plates, resting on steel bars welded to the old laterals drilled along their sides, are held in place with studs, nuts and washers of phosphor-bronze.

had reduced the loss of head during the 26 inch wash rate to 12 inches of water, or *just one-half*. The cost was about five dollars.

An Air-Water Brush

The following interesting disclosure may possibly be premature, but we shall take the chance in relating it at this time. For some time since the initial plate installation in 1939, there has been the temptation to utilize the porous plate botom as an air diffusing medium in order to obtain the scrubbing air-wash effect, particularly since the merits of this form of agitation have not been seriously discredited. It happened that the installation of rate-of-wash control in conjunction with a new steel all-welded wash water tank made it possible to introduce air along with the wash-water; and, moreover, without any cost for equipment or power. This was done by applying the aspirator principle.

A tap was inserted in the upper leg of a 12-inch tee having a 10-inch side connection to the rate-of-wash controller set between the tee and the wash water storage tank. The upper leg is normally valved off, being connected to the tank to by-pass the controller if need be at any time. The lower leg is joined to the 12-inch wash water line leading to the filters. The center line of the tee stands about 13 feet above the sand surface. By cracking the valve at the tap as the wash valve opens, adequate volumes of air are inspirated and carried by the wash water to the plates. In this way very good air distribution is secured over about two-thirds of the area of the bottom. Varying degrees of violence of sand agitation and circulation, depending upon the volume of air admitted, have been secured. By shutting down the air before the end of the wash, as is usual, the air is swept from the system by the finishing water wash.

Thus the entire sand mass may be subjected to a thorough going-over without auxiliary equipment. This novel water-air wash procedure is possible with the rigid sand supporting medium, and absence of gravel.

Adequate descriptions of porous plate installations have already appeared.[6] Certain refinements of detail and construction features which have been incorporated in the three new units provided at the Larchmont, N. Y., plant are being covered in an article to appear in "Public Works."

When the water level is drawn down below the sand in the three new units, the sand surface is almost carpet smooth. The accompanying picture, in which a fairly heavy blanket of alum floc and activated carbon has been retained on the sand, is hardly a substitute for visual inspection. From an operating angle the results with the first bottom of porous plates have been very gratifying.

References

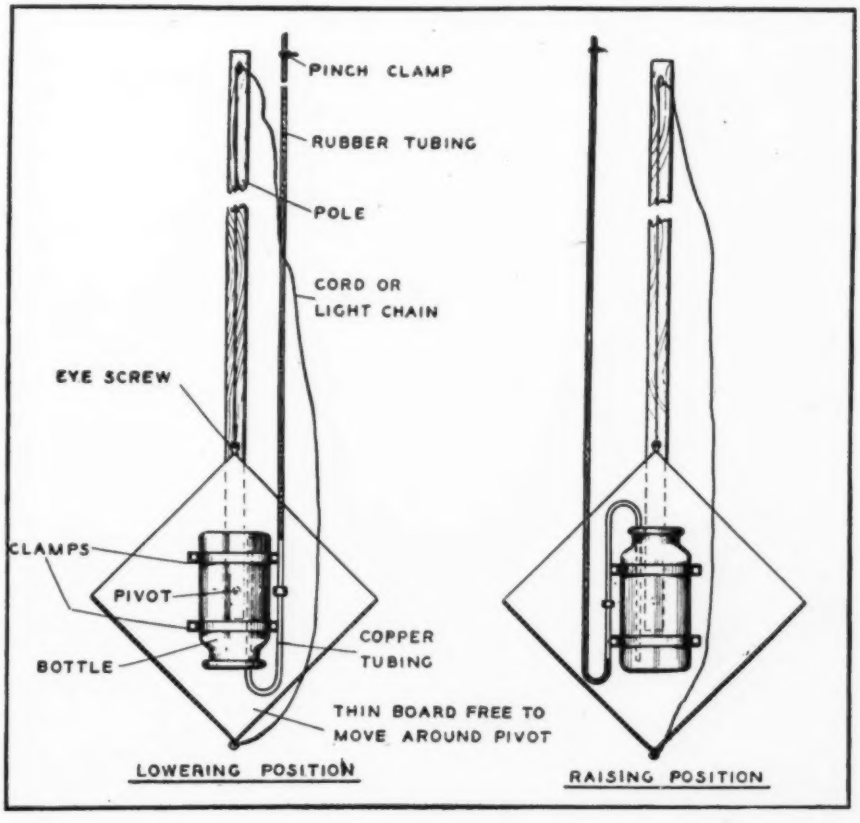
[1]Manual Eng. Practice No. 19 Am. Soc. C. E. (1940).
[2]J. R. Baylis, Water Wks. Eng. **93**, 1432 (1940).
[3]T. R. Camp, J. New England Water Wks. Assn. **49**, 1 (1935).
[4]J. Am. Water Wks. Assn. **16**, 542 (1926).
[5]H. T. Hotchkiss, Water Wks. & Sewerage **86**, 442 (1939).
[6]H. T. Hotchkiss, Water Wks. & Sewerage **86**, 442 (1939).
[6]H. T. Hotchkiss, Water Wks. & Sewerage **92**, 1426 (1939).
[6]L. R. Stevens, Water Wks. & Sewerage **87**, 111 (1940).

APPARATUS FOR COLLECTING FLOCCULATED SAMPLES*

THE apparatus shown on the accompanying sketch consists of a wide mouth bottle clamped to a thin board, which in turn is attached to a pole of suitable length. The board is free to rotate on the center pivot and may be turned by the string or light chain attached to the two opposite corners. The bottle may be vented through tubing which extends above the liquid surface.

When the bottle is lowered in inverted position, the pinch clamp on the vent line is closed. When the desired sampling level is reached, the pinch clamp is released, so that the floc containing liquid slowly enters the bottle as the air is released. When the bottle is full it is rotated and then raised to upright position with the pull chain.

Through use of this apparatus, flocculated samples from any liquid depth may be collected. The breaking up of flocs, such as occurs when samples are pumped or taken by means of a small mouthed bottle, is avoided.



Acknowledgment

This device employed in studies made by the authors at Ypsilanti, Mich., was perfected by Mr. Geo. Darby, Director of the Westport Laboratories of the Dorr Company. It is a modification of a somewhat similar device earlier developed at the Howard Bend Purification Plant at St. Louis, Mo.

*Contributed by A. J. Fischer and A. Hillman, The Dorr Co., New York City. Printed in Water Works and Sewerage for April, 1940.

LIQUID CHLORINE*

Properties of Chlorine

Chlorine is never found free in nature. Gaseous chlorine is manufactured by the electrolysis of a sodium chloride solution. It is then purified and liquefied by a process of compression and refrigeration. As an article of commerce, chlorine is an amber-colored liquid approximately one and one-half times as heavy as water. It is marketed in steel containers which are under pressure. In Fig. 1 is shown the relation between temperature and vapor pressure.

When the pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times as heavy as air. Chlorine is non-inflammable, non-explosive, and a non-conductor of electricity. Generally speaking, in the absence of moisture it is not corrosive to common metals. In the presence of moisture gaseous chlorine reacts avidly with a majority of known substances.

Following is listed the more important chemical and physical properties of chlorine at standard conditions (32° F. and 1 atm. pressure) unless otherwise noted:

	Atomic	Molecular
Chemical Symbol for Chlorine....	Cl	Cl_2
Chemical Weight Relationship...	35.457	70.914
	Gaseous Chlorine	Liquid Chlorine
Specific Gravity	2.49* (air = 1)	1.47† (water = 1)
Weight per Cubic Foot...	0.201 lb.	91.70 lb.
Volume per Pound	4.98 cu. ft.	0.011 cu. ft.
Specific Heat		0.2230†
Liquefying Point		— 28.5° F.†
Freezing Point		—151.6° F.‡
Latent Heat of Evaporation		121.0 B.t.u.†
Critical Temperature		294.8° F.†
Pressure at Critical Temperature		1233 lb. per sq. in.
1 Volume Liquid		456 vol. gas

*Leduc †Kneitsch ‡Lange

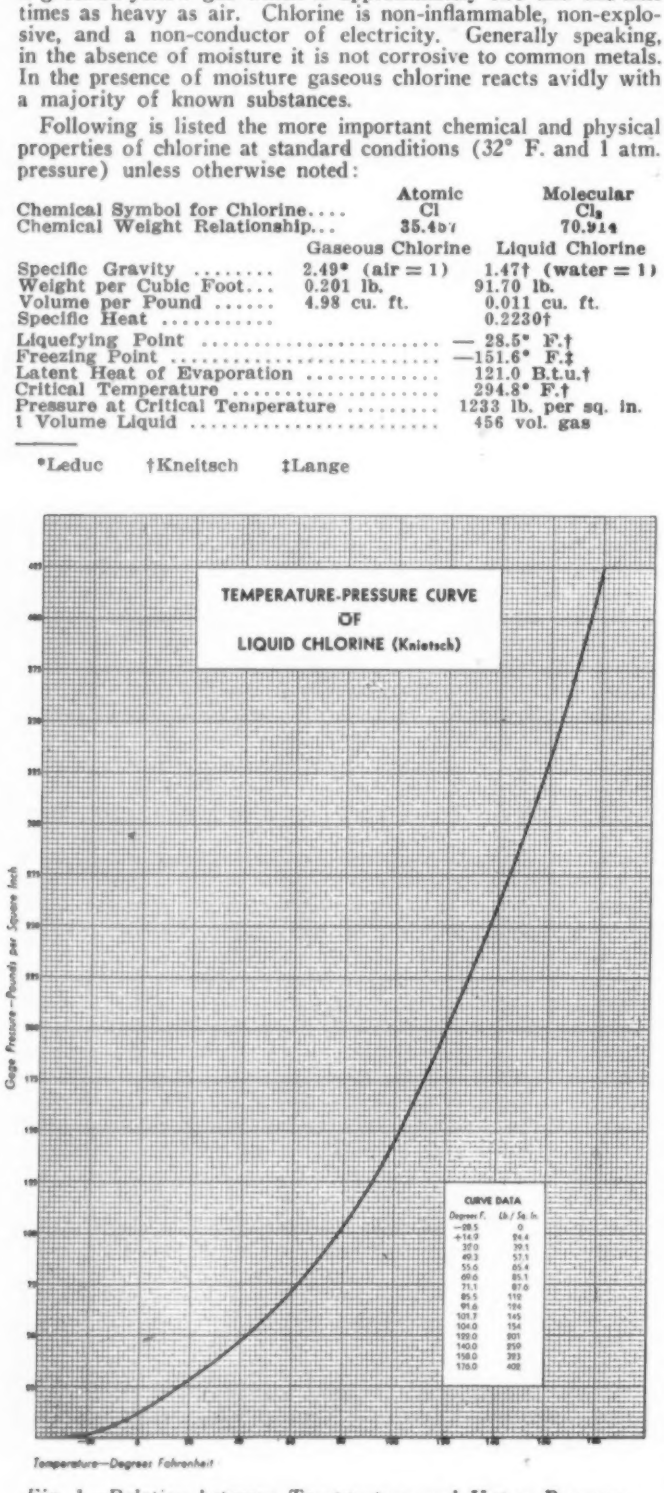


Fig. 1—Relation between Temperature and Vapor Pressure

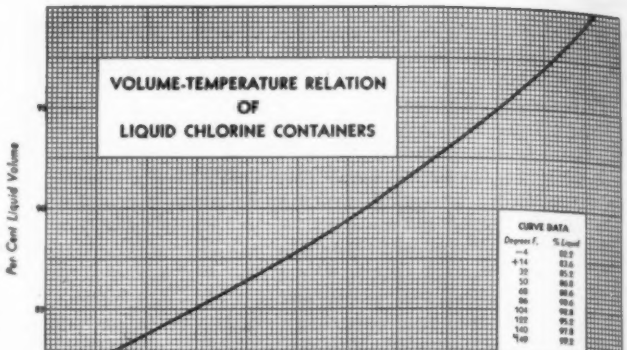


Fig. 3

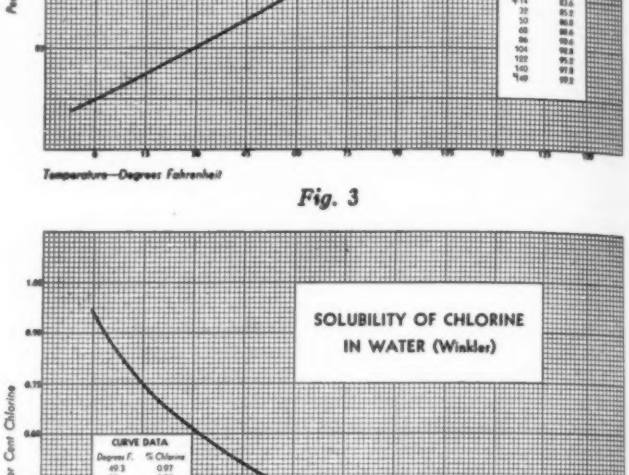


Fig. 4

A better visualization of those properties which are more serviceable can be obtained by studying the following charts and tables.

The compressibility coefficient of liquid chlorine is more than that of any other liquid element (approximately 0.0118% vol. /atm.). Its density decreases quite rapidly with increasing temperature. It is obvious from an examination of Figure 3 that above 156° F. a cylinder loaded to legal limits is subjected to hydrostatic pressure which will rupture it. Therefore, it is most important that the cylinder be kept safely below this temperature in any circumstances.

Chlorine is only slightly soluble in water. As depicted by Figure 4, its maximum solubility in distilled water is approximately 1% at 49.2° F. Below that temperature chlorine crystallizes in the form of chlorine hydrates, their composition depending upon conditions.

Liquid Chlorine Containers

Cylinders

Cylinders for shipping liquid chlorine by express, less carload, or box carload freight, are of various sizes ranging from 10 pounds net to 150 pounds net.

WEIGHTS OF 100 AND 150-LB. CYLINDERS

Net Contents	100 pounds	150 pounds
Average Tare Weight	93 pounds	123 pounds
Average Gross Weight	193 pounds	273 pounds

Minimum carloads comprise one hundred and fifty 100-pound cylinders or one hundred and eleven 150-pound cylinders.

Figure 6 illustrates the standard chlorine cylinder valve designed by the Chlorine Institute and now used by nearly all chlorine shippers. The stem "A" is of Monel metal and one complete turn in a counter-clockwise direction opens the valve so as to permit the maximum discharge of gas. A "frozen"

*From a bulletin on "Liquid Chlorine," prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.
*From "Liquid Chlorine," a Pennsylvania Salt Mfg. Co. bulletin.

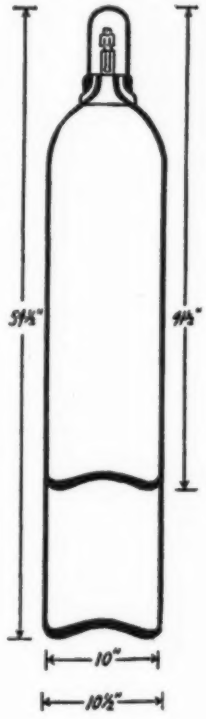
stem can usually be freed by slightly loosening the packing nut "C," tapping the top of the stem lightly, and then giving the valve wrench a sharp rap with the palm of the hand. The body "B" is a bronze and all connections to it are tightened by turning in a clockwise direction. Gas leaks around the stem can be checked by tightening the packing nut. *Under no circumstances tamper with safety plug "D."* It is below the valve seat and, therefore, cannot be controlled by the valve. Fusible metal in this plug softens at temperatures exceeding 157° F., hence cylinders should never be exposed to such temperatures for even short durations.

The valve outlet threads are standard ¾-inch hose coupling to which an auxiliary valve (containing a fiber or lead gasket) may be connected. However, these threads are bronze and are easily damaged. The clamp and adaptor shown in Figure 7 is the more practical type of connection.

Handling Cylinders

The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70° F. is approximately 35 pounds per 24 hours for a 100- and 150-pound cylinder. This rate may be increased by improving the circulation of air around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100° F. Even this procedure is questionable if used in conjunction with a chlorinator because uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities. (See Fig. 9.)



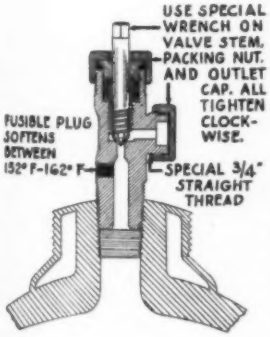
Cross Section of 100- and 150-Pound Cylinders

Fig. 5—Various Sizes of Cylinders

As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures which could have been avoided by closing the cylinder valve as soon as the cylinder is empty.

Multiple Unit Tank Cars—Ton Containers

The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car.


USE SPECIAL WRENCH ON VALVE STEM.
PACKING NUT AND OUTLET CAP. ALL TIGHTEN CLOCKWISE.
FUSIBLE PLUG SOFTENS BETWEEN 152° F-162° F.
SPECIAL ¾" STRAIGHT THREAD
Fig. 6—Cross Section of Standard Cylinder Valve

Each of the unit containers holds 2000 pounds of chlorine. *This shipping container is authorized by the Interstate Commerce Commission for common carrier movement only as an integral part of a fifteen unit car. Multiple unit and tank cars may be consigned only to private sidings, or to approved public sidings.* (*Par.* 431*B I. C. C., Regulations as amended* 1933.) Where unloading conditions are ideal it is a useful package of chlorine because its units are of such size as to permit reasonable movability yet not requiring the frequent changing necessary when using small cylinders.

Each container is equipped with 2 valves, 2 internal eduction pipes, 3 fusible (157° F.) safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 pounds of chlorine per day.

Handling Ton Containers

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists.

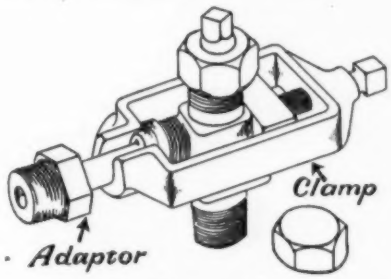


Fig. 7—Clamp and Adapter

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 12. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing, which procedure produces material saving in floor space.

The clamp and adaptor connection previously illustrated is recommended as the most practical and flexible connection for container valves. Wrenches for operating these valves should never be longer than seven inches.

Four hundred and twenty pounds per 24 hours is approximately the maximum rate of gas withdrawal for a ton-container at 70° F., operating against 35 pounds per square inch back pressure. This rate may be increased by improving the air circulation around the container, or by raising the room temperature. *Ton containers should never be subjected to the direct application of heat because of the danger of melting the fusible plugs.*

Single Unit Tank Cars

Single unit chlorine tank cars are of two sizes, holding approximately 32,000 and 60,000 pounds of chlorine each. Located in the dome are two liquid withdrawal valves on the longitudinal axis, two gas valves on the transverse axis, and a safety valve. Each liquid eduction pipe is fitted with a vertically acting ball check which stops the flow of liquid chlorine from the car in case of unloading line breakage, sudden opening of valve, or very heavy withdrawal rates.

The withdrawal of gaseous chlorine from any liquid chlorine container causes refrigeration and subsequent pressure reduction in the container. This effect is markedly increased by the cork insulation on single unit tank cars, and consumers purchasing their chlorine requirements in single unit tank cars may find it necessary to use liquid chlorine vaporizers on their operation requiring chlorine gas. Vaporizers usually employ hot water or steam as their heat sources, and may be equipped with either open or closed jackets.

Piping and Fixtures

A copper tubing built for 500 pounds per square inch working pressure is the preferred material for connecting all chlorine containers to permanent pipe lines.

Dry Chlorine

Black iron pipe is recommended as the preferable material for dry gaseous or liquid chlorine, although steel, copper, or other metal piping which will resist high pressures may be used. While standard weight pipe is satisfactory for all normal chlo-

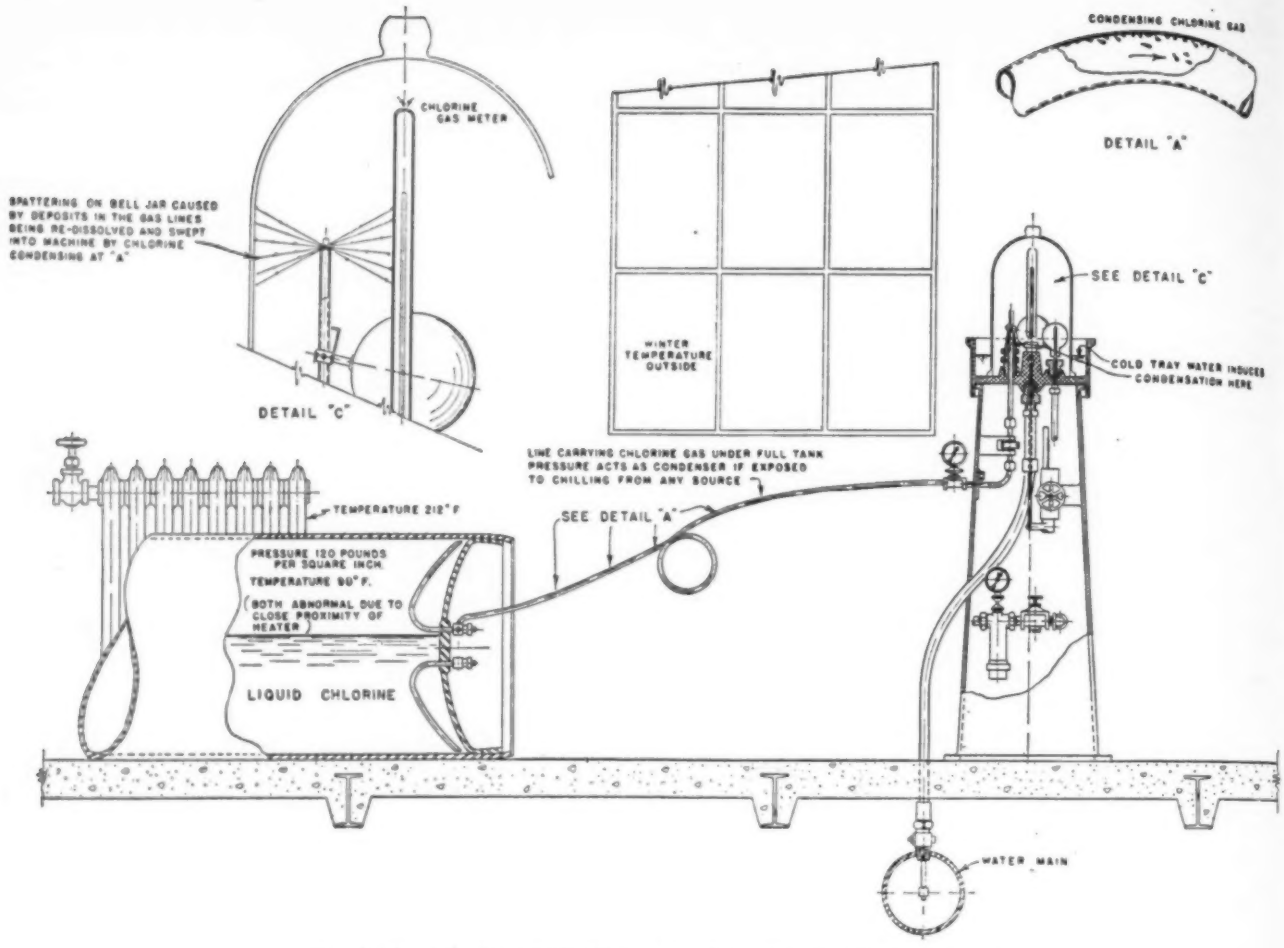

CONDENSING CHLORINE GAS
DETAIL "A"
CHLORINE GAS METER
SPATTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
DETAIL "C"
WINTER TEMPERATURE OUTSIDE
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
TEMPERATURE 212° F
PRESSURE 120 POUNDS PER SQUARE INCH
TEMPERATURE 90° F.
BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER
LIQUID CHLORINE
WATER MAIN

Fig. 9—Condensation Difficulties Caused by Uneven Temperatures

rine pressures, the extra heavy variety is recommended as safer and more practical since abnormal temperatures caused by fires, mechanical strains due to displacements, and corrosion produced by the entrance of moisture are all factors which should be considered. Liquid chlorine lines should be as free from bends and obstructions as possible. Where maximum discharge rates or lifts are required, pipe friction losses should be reduced by using lines of ¾ inch or more in diameter.

Hard rubber pipe is satisfactory for chlorine gas, but should never be used for conveying liquid chlorine. Pressure should not exceed 50 pounds and 80 pounds for the standard and extra heavy hard rubber pipe respectively. *Lines conveying gaseous chlorine should be run on a continuous upgrade in order that condensed (re-liquefied) chlorine will run back into the container.* Where this is impractical, drip legs should be provided in the low points of the pipe line. These legs should terminate in pockets which will assure evaporation of the liquid chlorine. *Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary.*

Pipe joints may be made with standard couplings, unions, or flanges. Standard ammonia flanges are preferable, since their use permits easy inspection and repair to lines. Gaskets should be of lead or asbestos composition. Only special valves for chlorine service should be employed. Usually, the body is of steel or special bronze, and the stem is of Monel metal. Graphite coated asbestos and rubber covered asbestos are recommended for packing. Flanged valves are preferable. Gauges should be of the diaphragm type for chlorine service. *Equipment and lines carrying dry chlorine should not be exposed to excessive heat.*

Wet Chlorine

Wet chlorine is very corrosive to all of the common metals. Materials contacting it must be of earthenware, glass, rubber, one of the special alloys, or noble metals. The handling of wet chlorine is an individual plant problem and specific recommendations can be made only after a survey and study of the various factors involved.

Employee Protection

1. Every person whose duties may cause exposure to chlorine should be provided with a gas mask of a design approved by the U. S. Bureau of Mines for chlorine service. Any canister gas mask is unsafe when chlorine concentration in the air exceeds one per cent (1%) or when the oxygen content is less than sixteen per cent (16%) by volume. In such cases oxygen breathing apparatus is required.
2. Individual gas masks should be provided and spare gas masks and canisters available in case of emergency. Complete familiarity with the mask and its maintenance is essential. A BAD GAS MASK IS WORSE THAN NO GAS MASK.
3. Periodic strict inspection and maintenance of approved gas masks are essential. Frequent drills in the use of gas masks are advisable.
4. Daily inspection of all loaded cylinders, ton containers, or tank cars is advisable in order to avoid developing a major leak. A small leak detected in its early stages can usually be stopped by immediate attention.

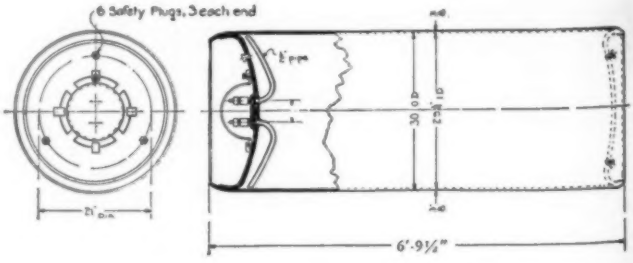


Fig. 12—Cross Section of a Ton Container

Leaks

5. When the odor of chlorine indicates a leak, authorized persons equipped with gas masks should immediately investigate. All other persons should leave the affected area.
6. Locating Leaks—Wrap a rag on a stick and soak it in ammonia water and swab the suspected points. A white smoke will show the point of leak.
7. Stopping Leaks—Shut off the chlorine supply if the leak is found in the pipe or equipment. All chlorine container valves close clockwise.
8. If the container leaks, move it outdoors or, in the case of a tank car, to the point on the consumer's private tracks where it will do the least harm. Leaking containers and tank cars will not be accepted by railroads or other carriers for shipment.
9. Leaks around valve stems may be stopped by tightening packing nuts. All standard chlorine valve packing nuts tighten clockwise. The construction of the valves is shown on this sheet.
10. Keep the head high (chlorine is heavier than air and seeks the lowest possible level). Keep to the windward side of a leak.
11. All leaks may be lessened by lowering the pressure in the container by withdrawing chlorine gas as rapidly as possible. If the consumer's process will not take the gas rapidly enough, an absorber may be made quickly in a barrel or suitable tank by dissolving 25 pounds of flake or solid caustic soda in 10 gallons of water. One and one-quarter pounds of caustic soda will be needed for each pound of chlorine absorbed. The chlorine gas is passed into the solution through a rubber hose or iron pipe.
12. Water played on a chlorine leak will not stop the leak. Water played on a leaking tank car always makes the leak worse. it will never dimish it.

What to Do in Case of Accidents

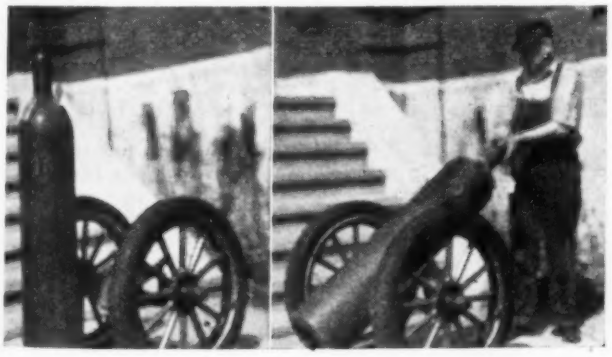
13. Carry patient from gas area. Patient should preferably be kept in a room at about 70° F. Supply blankets if necessary. Keep patient warm and quiet. Rest is essential.
14. Place patient on back with head and back elevated.
15. Call the physician immediately.
16. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin will provide irritation and acid burns. In such cases remove clothes and keep patient warm with blankets.
17. Give carbon dioxide and oxygen mixture which does not exceed 7% carbon dioxide. This mixture, already prepared, and sold with the necessary apparatus, can be administered intermittently for periods of two minutes followed by a two-minute rest over a total period not to exceed thirty minutes. Instructions of the purveyor of the gas apparatus should be carefully obeyed.
18. Milk may be given in mild cases as a relief from throat irritation.
19. If breathing has apparently ceased, start immediately the artificial prone pressure method of resuscitation (Shafer). Do not exceed 18 movements per minute.
20. Provide first aid as may have been prescribed for emergencies by your company physician pending his arrival.

Safety Cylinder Handling Carriage

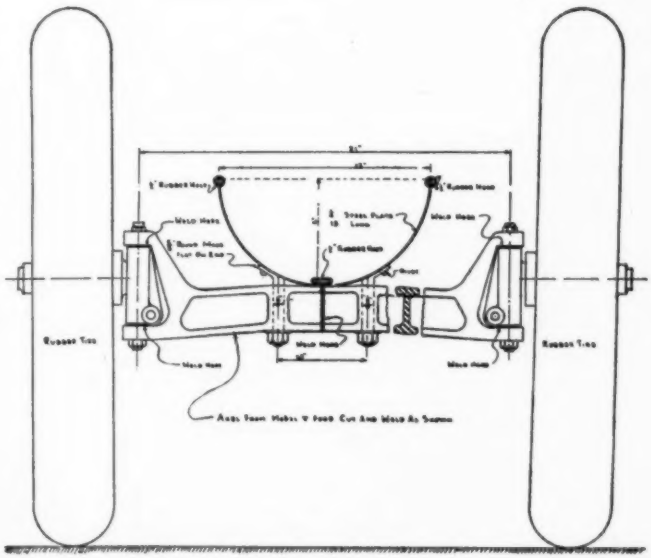
The accompanying pictures and detail sketch illustrate a novel, efficient and inexpensive carriage for transport of cylinders containing chlorine, ammonia or other compressed gases.

The device was designed and constructed from the wheels and front axle of what was once a Model "T" Ford automobile. Its ease of handling is self evident and its use saves many a "weak back" and avoids dangers of injury to the "strong men" around water and sewage plants.

To Edward J. Jenkins of the Philadelphia Suburban Water Company, Bryn Mawr, Pa., we are indebted for the illustrations of this unique cylinder truck which was developed in the above plant under his supervision.



In Position *Ready to Ride*



Model "T" Cylinder Carriage

Unique Carriage Designed for Cylinder Handling at the Water Purification Plant of the Philadelphia Suburban Water Co.

CHARACTERISTICS OF NATURAL WATERS

By CARL WILSON

Consultant in Water Treatment

Los Angeles, California

THE various characteristics which water manifests are due to its dissolved substances, hence a knowledge of them is of great importance to man. Besides these non-living substances all natural waters also contain living bodies, both vegetable and animal, and practically all of those changes in the character of water which produce spoilage are due to their activities.

In the following paragraphs an attempt will be made to briefly outline the outstanding effects upon water which are due to the principal constituents of the dissolved mineral load. Because water spoilage and the growths which give rise to it are of such vital importance to the water works operator special consideration will be given to the biological significance of several of these constituents.

Magnesium and Calcium Salts

Magnesium and calcium salts may be taken up first and discussed together, for they possess much in common. Both are abundant in the earth's crust, and both are readily soluble in water that contains carbon dioxide, which practically all water does. These elements are generally present in the form of bicarbonates, but sometimes they are combined as sulphates, and in some ground waters small amounts are present as chlorides, probably as a consequence of base exchange action exerted by soils.

In whatever form they may be present, salts of calcium and magnesium impart to water the property known as "hardness." Hard waters are undesirable for domestic use, and also for some industrial applications, because the calcium and magnesium react with the fatty acids of soaps to produce insoluble calcium and magnesium soaps which have no cleaning value and which float in the water as curdy flakes. So much soap is consumed in this way before a lather can be produced that hard waters are expensive to use. In addition there is the annoyance caused by the difficulty of washing the curdy material out of fabrics.

When hard waters are used for steam making they deposit their load of lime and magnesia upon the boiler tubes in the form of hard or soft scale. This coating not only wastes large amounts of fuel but causes the tubes to burn out through overheating. To improve hard waters for domestic and industrial use they must be softened, a proceeding which will be referred to again in a later paragraph.

For agricultural purposes calcium and magnesium are welcome constituents, and every irrigator hopes the water he uses may contain them in greater quantities than it does sodium and potassium, for salts of these latter bases cause "alkali" damage to soils and crops, while salts of the first two not only cause no such trouble, but may be made to rehabilitate a soil which has already been damaged by alkali.

Sodium and Potassium

Sodium and potassium are present in all waters. However, the potassium is so small in amount that it may generally be ignored and sodium regarded as the only alkali. In fresh waters, except those which are properly described as "alkali" waters, sodium is less in amount than calcium, the order of abundance being calcium, magnesium and sodium, while in sea water the order is exactly reversed, sodium being dominant and magnesium holding second place. In waters other than those intended for irrigation and some industrial uses sodium salts cause no trouble unless they are present in sufficient quantity to be perceptible to the taste, cause foaming in boilers or interfere with industrial processes, including laundrying.
esses, including laundering.

The acid radicles with which the bases are in equilibrium demand careful attention, for in some respects they seem more troublesome and more active than the bases. Six of them will be discussed here, viz., carbonate, bicarbonate, chloride, sulphate, nitrate and phosphate.

Carbonate, Bicarbonate and Carbon Dioxide

The carbonate radicle consists of one atom of carbon united to three atoms of oxygen, and is represented by the chemical symbol CO_3. It owes its characteristics to the carbon atom, as will be readily seen when we realize that if for the atom of carbon we substitute an atom of sulphur we have the sulphite (SO_3) radicle. Carbon makes carbonates just as sulphur makes sulphites and sulphates and nitrogen makes nitrates, represented respectively by the symbols CO_3, SO_3, SO_4, and NO_3. In some ways this carbon in carbonates is the most important element dissolved in water, especially in its effect upon the biology of water, but also as it affects certain aspects of water treatment. It occurs in water in three forms, viz., free carbon dioxide (CO_2), in the carbonate radicle (CO_3) and in the bicarbonate radicle (HCO_3).

Carbon dioxide (CO_2) is a colorless and almost tasteless gas which occurs as a by-product of metabolism, and is given off by all living things. It is produced in great quantities in lakes and streams wherever organic matter is being broken down under bacterial attack. Irrigation water percolating through the soil of cultivated fields carries this gas in solution to the subterranean reservoir to be pumped back to the surface from our wells. There are also deep sources of carbon dioxide from decomposing organic deposits laid down ages ago.

When it is dissolved in water carbon dioxide behaves in every way as though it had taken up the elements of water to form carbonic acid ($CO_2 + H_2O = H_2CO_3$), but carbonic acid has never been isolated in its natural state, and is known only in its compounds. Acting as an acid it combines with bases to form two classes of salts, viz., normal (or mono-) carbonates, such as calcium carbonate ($CaCO_3$), and bicarbonates (known as acid carbonates, since they retain one or two unreplaced hydrogen atoms), of which calcium bicarbonate $Ca(HCO_3)_2$ is typical. The bicarbonates of calcium and magnesium are readily soluble in water, while the corresponding normal carbonates are only sparingly soluble as such, but, and this is very important in water works practice, in the presence of free carbon dioxide (carbonic acid) these carbonates take up a molecule of carbonic acid and are converted into bicarbonates, so their solubility is a conditional characteristic dependent upon the environment.

Carbon is to be described as a "labile" element, for it moves readily from combination to combination, and in the living organism as well as in its by-products it migrates so regularly and easily that we speak of the "carbon cycle." Particularly in stored waters, but also to a lesser degree in ground waters, carbon is constantly moving around its cycle as it plays its role in the drama of life. To realize more fully the importance of this we have but to remember, that the manufacture of all food for the use of all living things, including man, starts with the linking of carbon dioxide and water which are built up into sugars and starches through the energy of sunlight acting upon chlorophyll in the cells of a green plant. All plants in water, including the plankton algae, are engaged in this task of manufacturing the primary food supply of the entire aquatic population. They first utilize the dissolved free carbon dioxide, but when this is exhausted they are able to indirectly release and use the half-bound carbon dioxide in bicarbonates, which are consequently changed to normal carbonates and removed from solution. In some instances this process has been observed to go so far in lakes as to result in a reduction of the total hardness by as great an amount as ten parts per million. It is interesting to note that if we could thus remove all the free carbon dioxide and convert all the bicarbonates to normal carbonates and maintain this condition (an impossibility) we would have no plankton algae to cause color, odor and taste in our water, for they would all starve to death for lack of available carbon. In this process of breaking down the bicarbonates to carbonates the pH value of waters have been known to be increased to 10.5 which is verging on causticity. At this point most of the algae die rapidly.

The carbonate radicle constantly comes into play in waters, and is a great aid in water treatment. To destroy growths of algae it is convenient to apply copper sulphate to water in reservoirs, using an amount seldom in excess of one part per million. When this is done the copper salt at first dissolves, but very quickly it reacts with the carbonate radicle to form a carbonate of copper which is insoluble and which settles out completely in a few hours, leaving the water copper free. The same reaction is helpful where copper pipes are used to carry water, for the carbonate radicle makes unlikely the occurrence of copper poisoning as it prevents copper from remaining in solution. If there

were no carbonates present this metal would remain in solution indefinitely and poisoning might result.

Chlorides

Chloride in potable waters is usually a minor constituent, although sometimes it may amount to 100 or 200 parts per million, at which concentrations it may be troublesome in waters which are put to certain industrial uses. The threshold value at which this radicle becomes perceptible to the taste is usually stated to be 250 parts per million.

Sulphates

The sulphate radicle (SO_4), when present in high concentration, especially if in equilibrium with sodium (forming Glauber's salt) or magnesium (Epsom salt) is likely to give water a laxative reaction. When it is in combination with calcium or magnesium it confers that property known as "permanent" or "non-carbonate" hardness, a condition which affects the choice of methods for softening treatment.

The essential element in the sulphate radicle is sulphur, which exhibits a "cycle" comparable to that of carbon. It is one of the elements which is indispensable to life and for this reason it is of great importance in the biology of water. It is quite as labile as carbon. Under the action of living organisms it passes readily from the elemental form to sulphuric acid, to sulphide and sulphate, and quite as readily reverses its path at any point in the cycle, hence it is not surprising to find it playing unexpected tricks to embarrass the unwary plant operator. When water containing considerable organic matter and sulphates (the amount of the latter radicle does not greatly affect the condition) is held in closed pipes so long that the dissolved oxygen becomes exhausted, then certain types of bacteria, which seem never to be missing, will attack sulphates for the purpose of liberating oxygen to satisfy their metabolic need, and sulphide is produced as a by-product, causing spoilage. If hydrogen sulphide is present it is likely to foster growths of an organism called Beggiatoa, which is unable to flourish except in the presence of this gas, and Beggiatoa in turn reduces the hydrogen sulphide to elementary sulphur, which may next be oxidized to sulphuric acid by other common bacteria. This acid then reacts with carbonates to form sulphates with the release of free carbon dioxide, and so these cycles roll onward, wheels within wheels, which turning reciprocally give rise to alternate life and death in the cycle of living organisms. Hydrogen sulphide in dead ends of distribution systems is indicated by "black-water" and vile odor when mains are flushed.

The Cycles Go On

One of the fundamental laws of science which water works operators must ever remember teaches that matter can never be destroyed; we can so greatly change its form that it may be unrecognizable to our senses, or we may tear its atoms asunder and dissipate them as smoke and ashes, but that matter still exists and it will later return in some new form which may be even more noisome. When we have once gotten rid of some objectionable substance, or compound, or organism, we must remain on guard lest, rising from its ashes, like the Phenix of old, it may haunt us anew, for the cycles which make life possible as well as the cycle which is life itself can be slowed down, but they cannot be permanently stopped. Successive plankton pulses follow each other throughout the year, each deriving part or all of its food from the degradation products of its predecessor.

Nitrates and Phosphates

Nitrates (NO_3) and phosphates (PO_4), are usually found in but small amount in unpolluted waters, but their biological importance is great, for both are essential plant foods, readily available to promote excessive development of plankton algae, or, worse still as far as odors and tastes are concerned, they support troublesome growths of bacteria. The nitrogen "cycle" is quite as vital to life as that of carbon or sulphur. The subtle causes which underlie the appearance of plankton "pulses" in lakes and reservoirs are believed to center in the limiting values of these two radicles, and in Europe considerable research has been directed toward the elucidation of this problem.

Iron and Manganese

Iron and manganese, two closely related metals, are sometimes found in troublesome quantity in surface waters, especially those contaminated by mine drainage or industrial wastes. More commonly either or both may be present in material amount in ground water, where they cause much trouble if water is to be used for domestic or industrial purposes. Water containing these metals is usually clear and sparkling as it comes from the ground, but after exposure to the air the metals become oxidized which renders them insoluble and they then cause the water to appear opalescent and later dirty owing to the separation of the oxides in flecks and masses. Such waters cause stains on clothes washed in them and upon plumbing fixtures. They also promote troublesome growths of an organism known as Crenothrix which may grow so abundantly in pipes as to greatly reduce their carrying capacity. Iron and manganese waters are common in Southern California and Crenothrix growths have been encountered in many of our large supplies. Both of these metals should be removed from water before it is admitted to pipe systems. Due to corrosive attack upon the pipes iron often causes trouble in a distribution system carrying water which at its source was iron free.

Borates and Fluorides

Boron is a metal which is found in small quantities in some waters but which is of little importance except when water is used for irrigation. When present in quantities exceeding 0.75 part per million, measured as elementary boron, it is likely to injure lemons and some other crops.

Fluorine is another troublesome element in waters in some localities. When present in water used by children, before the advent of their permanent teeth, this radicle causes an unsightly affliction of the teeth known as mottled enamel. The threshold value above which enamel damage is expected to appear is placed at 1.0 part per million of fluorine in the form of fluorides.

Treatment

The treatment accorded water to enhance its value for human use varies from simple settling to remove suspended matter to elaborate dosage with several different chemicals, aided by mechanical mixing, followed by retention to permit chemical reactions to reach completion, filtration to remove the products of reaction and final adjustment to stabilize the character of the finished water. Aeration is employed to remove odor, carbon dioxide, hydrogen sulphide, as well as iron and sometimes manganese. Coagulation with such chemicals as aluminum sulphate, sodium aluminate, ferric chloride, ferrous sulphate, etc., is employed to remove suspended matter which is so fine that it will not settle out, and filtration is used to remove the "floc" formed by the coagulant and with it most of the bacteria. Sterilization (the word is commonly employed, but it should be understood that it is a misnomer, as the resting stages of bacteria and other organisms are not destroyed) with chlorine, or sometimes by ozone or ultra-violet rays, is used to remove all trace of disease-producing organisms which might be present in the raw water. Activated carbon, in powdered and in granular form, is employed to remove objectionable odors and tastes.

Softening is generally accomplished by the addition of quick lime or hydrated lime to remove the carbonate hardness, and of sodium carbonate (soda ash) to remove the non-carbonate hardness. The soda-lime process obviously cannot reduce hardness below the solubility of calcium carbonate and magnesium hydroxide, a value which is in the neighborhood of 60 parts per million expressed as calcium carbonate ($CaCO_3$), depending on the pH.

Softening can also be effected by filtering water through beds of zeolite, which is a complex hydrated aluminum silicate that contains sodium loosely linked into its molecule. Calcium and magnesium in the hard water replace the sodium in the silicate and in this way water of zero hardness can be readily produced.

After a certain volume of water has been softened the zeolite becomes saturated with calcium and magnesium and can do no further work until it has been regenerated. This is accomplished by treating the zeolite with a strong solution of salt (sodium chloride) during which the sodium displaces the calcium and magnesium which are washed out into the brine. Zeolite softening has no effect upon the acid radicles as ordinarily practiced, but there is now available an exchange material which will effect the removal of carbonates and other acid radicals.

For a presentation of treatment plant operation and control, the writer wishes to urge all students of the subject to secure a copy of one small book which he considers the very best brief treatise of water purification, and one which is expressed in simple and direct language. It will answer most of your questions. The book is "Water Supply and Treatment," written by Charles P. Hoover, the leading exponent of water softening in America. It is published by the National Lime Association, Washington, D. C., as Bulletin No. 211, for distribution at 50 cents per copy.

INTERPRETATION OF CHEMICAL ANALYSES OF WATER

By JAMES M. MONTGOMERY
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WATER works men are continually being confronted with results of chemical analyses of waters and not infrequently are puzzled as to what the figures mean. It is hoped that the following will be helpful in interpreting and understanding such analyses.

Expression of Results

In the United States, the results of chemical analyses of water are expressed usually either as parts per million or as grains per gallon. One part per million is equivalent to one unit of weight of the substance being reported in one million units of water; as, for instance, one pound of the substance in one million pounds of water. Since one gallon of water weighs approximately 8.3 pounds, one part per million is equivalent to 8.3 pounds of substance in one million gallons of water. One grain per gallon means that each gallon of water contains one grain or 1/7000 of a pound of the substance being reported. One grain per gallon is equivalent to 17.1 parts per million or 143 pounds per million gallons.

TABLE 1

	Equivalents		
Unit	Grains per U. S. gallon	Parts per million	Pounds per million gallons
1 grain per U. S. gallon..	1.0	17.1	143
1 part per million.....	0.058	1.0	8.3

At one time analytical results were expressed quite generally in grains per gallon. The American Public Health Association, in its publication, "Standard Methods for the Examination of Water and Sewage," however, recommends that results be expressed in parts per million and the recent trend has been in that direction. In the treatment of water the dosages of chemicals employed are expressed in grains per gallon added, although modern trend is toward the use of lbs./m.g. for all chemicals involved.

Analytical results may also be expressed in terms which are readily understood chemically. The chemical formula or the name of the compound in terms of which each substance or radical is reported, should be given. For instance, if magnesium is reported as: magnesium hardness = 50 parts per million, it is difficult to determine immediately just how much magnesium the water contains. If, however, magnesium is reported as: magnesium hardness (expressed as $CaCO_3$) = 50 p.p.m., it is at once apparent that magnesium is present in an amount molecularly equivalent to 50 p.p.m. of calcium carbonate ($CaCO_3$). Only those results which are properly and completely reported can be properly interpreted.

Judging the Sanitary Quality of Water from Chemical Results

Before about 1890, it was customary to attempt to judge the sanitary quality of water from chemical analyses. Since the development of bacteriological methods, however, chemical analyses have been little used for this purpose except as a check or for comparative purposes. The substances determined and their significance from a sanitary standpoint will now be discussed briefly.

Four different forms of nitrogen are determined for a sanitary chemical water analysis. It is known that the nitrogen present in fecal matter is in the form of protein and that, starting from that form, the nitrogen goes through a cycle of changes whereby it is converted first from the protein or albuminoid ammonia form to so-called free ammonia (mineral ammonia), then to nitrite and finally to nitrate. The total amount of nitrogen, properly valued, indicates the extent of fecal pollution, and the relative amounts of the four forms of nitrogen indicate the extent to which oxidation has proceeded. Nitrates, however, may come from mineral deposits and alone have no sanitary significance.

The amount of oxidizable organic matter in water is indicated properly valued the latter also indicates the presence of organic pollution, but is a better indicator of industrial waste pollution than of sewage pollution.

Chloride is present in many waters, usually as sodium chloride, and in itself is harmless. Since, however, sewage contains a relatively large amount of chloride, any unusual increase in the chloride content of a water may be evidence of pollution.

Turbidity indicates the presence of suspended matter and may be either organic or inorganic. In order to meet U. S. Treasury Department Standards for Drinking Water, turbidity must not exceed 10 (silica scale) and in general it should not exceed 5.

As a measure of the sanitary quality of water, the above chemical analyses are of most value when used for comparative purposes. If these analyses are made as a matter of routine and the normal content of each for the water in question is well known, an increase above the normal might well be considered to indicate sewage pollution. Of greatest value are these tests in conjunction with well waters.

Alkalinity:

Alkalinity in water is determined by titrating a sample with N/50 acid using two indicators, phenolphthalein and methyl orange and is reported in terms of calcium carbonate. Bicarbonates, normal carbonates, and hydroxides, are the three types of compound which produce alkalinity in water and by using both phenolphthalein and methyl orange indicators, it is possible to determine how much of each type of alkalinity is present.

Methyl orange measures all of the alkalinity, bicarbonates, normal carbonates, and hydroxides. Phenolphthalein measures none of the bicarbonates, but does half of the normal carbonates, and all of the hydroxides. If phenolphthalein indicator is added to a solution containing only bicarbonate alkalinity, the solution will remain colorless. If added to a solution containing only normal carbonates the solution will turn red and, when titrated with standard acid, the end point to phenolphthalein will be exactly half way to the end point to methyl orange. This is because each milli-liter (ml.) of titrating acid releases an equivalent amount of carbonic acid which affects phenolphthalein the same as the titrating acid. If phenolphthalein is added to a solution containing only hydroxides, the solution will turn red and the end point to phenolphthalein will be exactly the same as the end point to methyl orange. If some of both normal carbonate and hydroxide are present the phenolphthalein end point will be somewhere between the two extremes cited.

Most natural waters contain bicarbonates only and normal carbonates and hydroxides are usually produced by lime treatment. The phenolphthalein-methyl orange titration makes it possible to determine quickly and accurately whether the proper amount of lime is being added to the water in softening or in corrosivity reduction with lime or other alkali.

When lime is added to a water containing calcium bicarbonate the following reaction takes place:

$$\underset{\text{(calcium bicarbonate)}}{CaH_2(CO_3)_2} + \underset{\text{(lime)}}{Ca(OH)_2} \longrightarrow \underset{\text{(calcium carbonate)}}{2CaCO_3} + \underset{\text{(water)}}{2H_2O}$$

The reaction takes place as shown in the equation when exactly the right amount of lime is added to the water to convert all of the calcium bicarbonate to calcium carbonate and, when titrated, the end point to phenolphthalein will be exactly half the end point to methyl orange because the alkalinity will be due to the small amount of calcium normal carbonate remaining in solution. If lime is added in insufficient quantity to react with all of the calcium bicarbonate, the water will contain both calcium bicarbonate and calcium normal carbonate and, when titrated, the end point to phenolphthalein will be less than one-half the end point to methyl orange. If lime is added in excess of the amount required to react with all of the calcium bicarbonate, the water will contain calcium normal carbonate and free lime or calcium hydroxide and, when titrated, the end point to phenolphthalein will be more than one-half the end point to methyl orange.

From the foregoing explanation, the following rules can be derived (Ph. = alkalinity to phenol. MO. = alkalinity to methyl orange; both expressed in parts per million):

1. If 2 Ph. is less than M.O., then 2 Ph. = normal carbonates
2. If 2 Ph. is more than M.O., then 2 Ph. — M.O. = hydroxides and M.O. — hydroxides = normal carbonates.
3. If 2 Ph. = M.O., then all alkalinity is due to normal carbonates.

If the alkalinity is less than the total hardness, then the alkalinity is due to carbonate hardness. If the alkalinity is more than the total hardness, then the total hardness is all carbonate hardness and the excess alkalinity (alkalinity — total hardness) is sodium alkalinity.

Hardness:

Hardness in water is due principally to compounds of calcium and magnesium which are in solution and to a lesser (usually inconsequential) extent, to compounds of iron and aluminum.

Hardness, like alkalinity, is expressed in terms of calcium carbonate. Hardness is determined in a number of ways, the most important being, by calculation, by the soap method and by the soda reagent method. (See "Standard Methods of Water Analysis"—A.P.H.A. and A.W.W.A.)

The most accurate method for determining the total hardness of a water is to compute the calcium carbonate equivalent of the calcium, magnesium and, if present in sufficient quantity, iron and aluminum content. Usually the iron and aluminum can be neglected. If a water analysis shows the calcium and magnesium content, the total hardness can be computed as follows:

$$Ca \times 2.495 + Mg \times 4.115 = \text{hardness as } CaCO_3$$

The soap method is the most rapid means of determining hardness but is also the least accurate, especially when the determination is made by an inexperienced person. Hardness as determined by the soap method should always be considered as approximate and, if accuracy is necessary, some other method should be employed. This is especially true of the determination of calcium hardness from the false end point or ghost point in the soap hardness determination.

Either total hardness or non-carbonate hardness can be determined by the soda reagent method. Due to the fact that calcium carbonate and magnesium hydroxide are slightly soluble, this method is not strictly accurate but is sufficiently so for routine control work. The soda reagent method is commonly used in controlling the operation of lime-soda ash water softening plants.

When results of hardness determinations of water are being studied and interpreted, it is always well to know the method of analysis used. Then the proper weight can be given to the results reported.

Dissolved Gases

Free carbon dioxide and dissolved oxygen are often determined in making complete water analyses. The accuracy of the results reported for these two gases depends to a great extent upon the accuracy with which the samples are collected. It is always well to bear in mind that while the analyses may be accurate, the sample may have been collected in such a way as to allow the escape or absorption of considerable amounts of gas.

When results are reported in terms of positive and negative radicals the figures are usually unsatisfactory to the layman because they give but a hazy idea of the composition of the water. The results are more readily understood if hypothetical combinations are calculated or if the results are expressed graphically

Computing Most Probable Compounds

In computing hypothetical combinations, the method of Hale (Jour. Am. Chem. Soc., 29, 1078; 1907) is usually used. In this method, the positive and negative radicals are combined with each other in the following order:

Calcium	Bicarbonate
Magnesium	Sulphate
Sodium	Chloride
Potassium	Nitrate

Calcium is first combined with bicarbonate. If there is excess calcium above that required for bicarbonate, it is combined with sulphate, chloride, and nitrate, until exhausted. If there is excess bicarbonate above that required for calcium, it is combined with magnesium, sodium, and potassium, until exhausted. As each positive and negative radical is used up, the next following radical is combined until the radicals on both sides are exhausted. If the analysis has been made correctly, the positive and negative radicals will be present in equivalent amounts.

The first step in calculating hypothetical combinations is to determine the reacting values of each of the positive and negative radicals in the water in accordance with the following formula, in which (R) is the radical in question:

$$\text{Reacting value} = (R) \text{ in p.p.m.} \times \frac{\text{valence of } (R)}{\text{mol. wgt. of } (R)}$$

The term $\frac{\text{valence of } (R)}{\text{mol. wgt. of } (R)}$ is called the "reaction coefficient," and for various positive and negative radicals has values as follows:

REACTION COEFFICIENTS

Positive radicals	Negative radicals
Calcium (Ca) 0.0499	Carbonate (CO_3) 0.0333
Magnesium (Mg) 0.0822	Bicarbonate (HCO_3) 0.0164
Sodium (Na) 0.0435	Sulphate (SO_4) 0.0208
Potassium (K) 0.256	Chloride (Cl) 0.0282
Hydrogen (H) 0.992	Nitrate (NO_3) 0.0161

The following is a typical water analysis giving the various positive and negative radicals in parts per million and the calculated reacting values:

Analysis			Reacting Value	Analysis			Reacting Value
Ca	81	× .0499 =	4.04	HCO_3	177	× .0164 =	2.90
Mg	25	× .0822 =	2.05	SO_4	180	× .0208 =	3.74
Na	30	× .0435 =	1.31	Cl	27	× .0282 =	.76
			7.40				7.40

The reacting values give a measure of the relative amounts of the positive and negative radicals present in the water. The 81 p.p.m. of calcium, with a reacting value of 4.04, is present in sufficient amount to combine with all of the bicarbonate and with 4.04 — 2.90 = 1.14 of the reacting value of the sulphate—second in the order of negative radicals to combine with calcium. Magnesium, with a reacting value of 2.05, is not present in sufficient amount to use up all of the sulphate remaining and 3.74 — (1.14 + 2.05) = .55 of the reacting value of the sulphate remains to combine with the sodium. The reacting values will be distributed and evaluated as follows:

Ca as calcium bicarbonate	2.90
Ca as calcium sulphate	1.14
Mg as magnesium sulphate	2.05
Na as sodium sulphate	.55
Na as sodium chloride	.76
Total	7.40

Determining Actual PPM. of Each Compound

In order to determine the actual amount of each hypothetical combination present in parts per million, it is necessary to multiply the reacting value by a combination factor. The combination factor is the factor necessary to convert the radical reported into the compound sought divided by the reaction coefficient. For instance, the factor for converting Ca to $CaCO_3$ is 2.5 and the reaction coefficient for Ca is .0499. The combination factor for converting the reacting value for Ca to $CaCO_3$ will therefore be 2.5 ÷ .0499 = 50. The following is a table of combination factors:

Given the Reacting Values	Sought	Combination Factor
For Ca or CO_3	$CaCO_3$	50.0
For Ca or SO_4	$CaSO_4$	68.1
For Ca or Cl	$CaCl_2$	55.5
For Ca or NO_3	$Ca(NO_3)_2$	82.0
For Mg or CO_3	$MgCO_3$	42.2
For Mg or SO_4	$MgSO_4$	60.2
For Mg or Cl	$MgCl_2$	47.6
For Mg or NO_3	$Mg(NO_3)_2$	74.2
For Na or CO_3	Na_2CO_3	53.0
For Na or SO_4	Na_2SO_4	71.0
For Na or Cl	NaCl	58.5
For Na or NO_3	$NaNO_3$	85.0

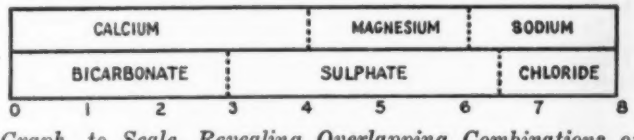
Applying the combination factors to the above analysis, the following hypothetical combinations are obtained:

Calcium bicarbonate ($CaCO_3$)	2.90 × 50.0 =	145 p.p.m.*
Calcium sulphate ($CaSO_4$)	1.14 × 68.1 =	78 p.p.m.
Magnesium sulphate ($MgSO_4$)	2.05 × 60.2 =	123 p.p.m.
Sodium sulphate (Na_2SO_4)	.55 × 71.0 =	39 p.p.m.
Sodium chloride (NaCl)	.76 × 58.5 =	44 p.p.m.

*Bicarbonate $Ca(HCO_3)_2$ in terms of $CaCO_3$

Graphical Plotting to Picture Combinations

Reacting values may also be plotted graphically to show the relative amounts of each radical present. If the reacting values for Ca, Mg, and Na are laid off to scale in that order on one line, and the reacting values for HCO_3, SO_4, and Cl are laid off to scale in that order on another line directly under the first, the relative amounts of each are at once apparent. On the chart, the reacting values given above have been plotted:



Graph, to Scale, Revealing Overlapping Combinations of Radicals and Clearly Revealing a Picture of Chemical Make-up of Waters.

When properly interpreted, results of chemical analyses of water are very valuable in determining the quality of the water, and the treatment necessary to improve the quality.

INFILCO INC.

Water Conditioning, Sewage Treating, Hydraulic Control and Chemical Feed Equipment

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PRODUCTS

ACCELATORS—Clarifying, softening and stabilizing
AERATORS—Multi-Cone, forced draft, coke tray and cascade; floating and adjustable cone aerator nozzles
BOILER FEED WATER TREATMENT PLANTS—Softener and silica removal
CARBON (Activated) PURIFIERS—Taste, odor and color removal plants
CHEMICAL FEEDERS—Dry and solution types, combination mixers and feeders
COLOR REMOVAL PLANTS
CONTROLLERS—Chemical feed, rate of flow, liquid level and hydraulic valve
DEMINERALIZATION PLANTS FOR WATER AND SUGAR
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GAUGES—Rate of flow, loss of head, liquid level, etc.
ION EXCHANGER PLANTS
LIME FEEDERS AND SLAKERS
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VENTURI TUBES
WATER FILTERS AND FILTER PLANT EQUIPMENT
WATER SOFTENING PLANTS OF ALL TYPES
ZEOLITES AND ZEOLITE WATER SOFTENERS

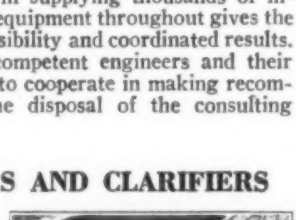
WATER CONDITIONING EQUIPMENT

INFILCO SERVICES

INFILCO has specialized in the design and manufacture of all kinds of water conditioning equipment—from Accelators to Zeolites—for over forty years.

The consulting engineer or his client can specify "Infilco" throughout the water treating plant knowing that such equipment has the benefit of Infilco's vast experience in supplying thousands of installations. Specifying one brand of equipment throughout gives the added assurance of undivided responsibility and coordinated results. The services of Infilco's staff of competent engineers and their complete laboratory facilities, ready to cooperate in making recommendations and reports, are at the disposal of the consulting engineer or his client.

ACCELATOR SOFTENERS AND CLARIFIERS

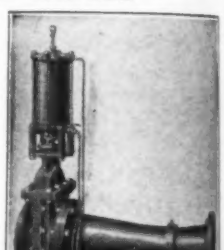


The Accelator for water softening and clarifying is one of the most important water treating developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space and in a single unit. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco Zeolite Softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic or full automatic operation as desired. A variety of Infilco Zeolites are available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco Zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CONTROLLERS AND GAUGES



Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

PRESSURE AND GRAVITY FILTERS

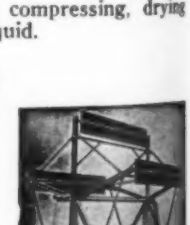
Clean, clear water is assured by Infilco pressure or gravity type filter plants. Capacities range upward from a hundred gallons per day. Models range from conventional-type filters to the new, light-weight Stellar. The Stellar filter utilizes the principle of filtering through a bed of filter-aid (usually diatomaceous earth) supported on the outside of rigid Stellar elements.

The design of every Infilco filter plant is based upon sound engineering principles, backed by over four decades of experience.

RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

COAGULATORS



Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

TRANSFER SWITCHES, OPERATING TABLES ROBOTROLS AND SAMPLING TABLES

Infilco Transfer Switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

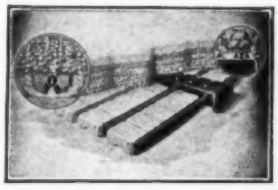
The Robotrol is a robot filter, or softener, operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently and without supervision.

Sampling tables furnish a visual check on the condition of raw, settled and filtered water.

HYDRODARCO PURIFIERS

Hydrodarco is the activated carbon made expressly for water purification. Hydrodarco Purifiers, employing beds of granular Hydrodarco, automatically remove tastes, odors, chlorine, iron, organic color, etc. They are furnished in capacities from a few gallons per hour to millions of gallons per day.

INFILCO FILTER UNDERDRAINS



Wagner Filter Underdrains provide a primary distributing system of a manifold and laterals on wide centers, with distributing orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

FLUOREX PURIFIERS

Fluorex is a specially prepared, highly porous and reactive tricalcium phosphate for removing fluorine from water. Fluorex Purifiers, with their improved method of regeneration which prolongs the active life of the adsorbant and makes possible the use of ordinary materials and construction, offer the ideal means of removing fluorine.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

SEWAGE TREATING EQUIPMENT

INFILCO manufactures equipment for all sewage treating processes—chemical, biological and mechanical. In offering many products for application in these various processes, Infilco also offers the user the advantage of centralized responsibility, which is important in assuring continued satisfactory equipment operation.

ACCELO BIOX PROCESS

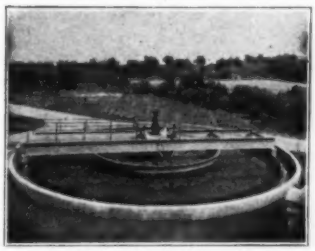
Accelo Biox is Infilco's name for a high rate activated sludge process involving direct recirculation of aeration tank mixed liquor. This process has produced results comparable to those obtained in conventional activated sludge plants, and it employs only half the aeration tank volume and blower capacity. The resulting savings in initial investment and operating cost are readily apparent. Recommendations embodying the Accelo Biox Process are available for any sized plant.

ACCELO-FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the sewage at a considerably higher filter dosage rate.

Aero-Spray Nozzles on a rotary distributor (above) provide a fan-shaped variable spray which assures optimum coverage and maximum aeration in the application of screened, settled sewage to trickling filters. All parts of these improved nozzles are bronze to assure long life.

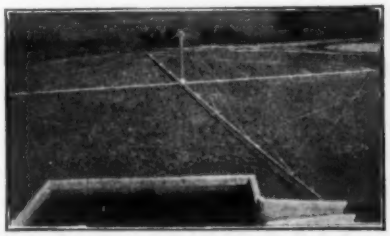
CLARIFIERS



Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation of a sewage concentrator. These Clarifiers are designed with curved rotating scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

Infilco Clarifiers assure effective removal of solids from the sedimentation tank whether it be small or large. The WS Clarifier with central motor reducer drive is supplied for tank diameters up to 40 feet. For diameters larger than 40 feet, there is the PD Clarifier, driven by a vertical motorized reducer through a submerged synthetic latex covered wheel.

ROTARY DISTRIBUTORS AND DOSING SIPHONS



Only Infilco Rotary Distributors offer so many important refinements such as full-opening arm end gates, mercury seal with protective seal ring, and corrosion-resistant nickel iron castings, along with low operating head requirements and uniformity of distribution. Infilco dosing siphons insure perfect operation of distribution mechanism at all flow rates.

THE PERMUTIT COMPANY

World's Foremost Manufacturer of Water Conditioning Equipment

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This revolutionary new equipment removes hardness and suspended solids in a much shorter detention period, saves chemicals, takes only half the space of old-type plants. The raw water and chemicals are mixed in a compartment where they are agitated with the suspended sludge from previously treated water. This speeds precipitation. The water and precipitates then pass into the filter upflow compartment which has a gradually increasing cross-section. The gradually reduced velocity of upflow supports the sludge filter at uniform density throughout the filtering zone. A rate of flow is reached at which the sludge is no longer supported, forming a clearly defined top to the sludge blanket. The effluent is clear, and for some purposes may not need further filtration.

Permutit makes every type and size of water conditioning equipment. Here are a few:

ZEOLITE WATER SOFTENERS

In Permutit's pressure zeolite softeners, a single multi-port valve, operated automatically or manually, conducts the raw water into a shell. The water is then evenly distributed through a bed of zeolite, and after collection flows to service completely softened. The valve also controls backwashing to clean the bed, regeneration with brine, and rinsing. Gravity zeolite units are also available.

PERMUTIT'S SPIRACTOR

The new cold lime soda water softener based on "catalytic precipitation" principle. Soft water in 8 minutes . . . no settling or voluminous sludge . . . Saves space and time.

PERMUTIT'S DEMINERALIZER

Produces a water practically free of all salts; at a fraction of the cost of distillation.

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Automatic and manual, gravity and pressure.

IRON REMOVAL FILTERS

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330 West 42nd St. — New York 18, N. Y.

WATER CONDITIONING HEADQUARTERS

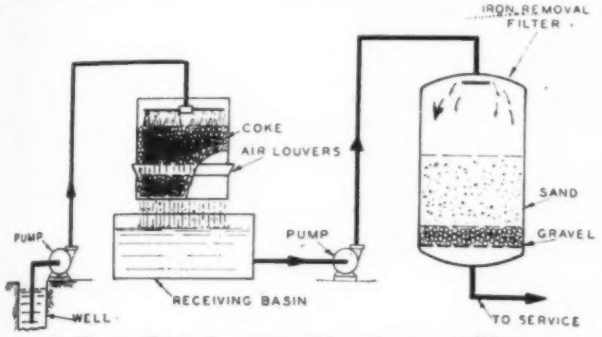
REMOVAL OF IRON AND HARDNESS

By DANIEL J. SAUNDERS

The Permutit Company, New York, N. Y.

The following describes some of the difficulties experienced in industry and in the home due to the presence of iron and hardness in water and, at the same time, outlines methods that can be employed to overcome such difficulties, under varying sets of conditions.

When iron is present in a water supply in an amount greater than 0.3 p.p.m., it causes unsilghtly yellowish or black stains on bathroom fixtures, gives a metallic taste to drinking water, reacts with other reagents used in dye houses, laundries, paper mills and tanners where, for example, it combines with tannin in leather and forms black iron tannate; deposits in Municipal distribution systems, thus not only increasing the friction through



A Simple Coke Aerator and Iron Removal Filter.

the mains which increases pumping costs, but at sudden high rates of flow these deposits loosen iron rust itself which is delivered to the users. Further, the growth of iron bacteria, such as Crenothrix, is also promoted by its presence.

The type of treatment plant required to remove iron is determined by a number of factors such as: character of the water (especially the factors interfering with oxidation reactions) engineering conditions and the purpose for which the water is to be used.

Iron and Manganese Removal

In general, iron (also manganese), can be removed from well waters by two methods:

1—Oxidation to the insoluble higher oxides and hydrates followed by filtration.

2—Removal by base exchange, by employing correctly selected base exchange zeolites.

However, all waters and particularly surface supplies, do not respond readily to oxidation reactions. As just mentioned, there are interfering factors to be given consideration such as:

Free Carbon Dioxide

High amounts of free CO_2 or any acid will interfere with the oxidation reactions going to completion. Therefore, in such cases thorough aeration, or addition of alkalis, or both, are necessary. The addition of only 0.14 p.p.m. of oxygen per 1 p.p.m. of iron is theoretically required in the normal oxidation reaction. This quantity is insufficient when free CO_2 or any acid is present.

Low Total Solids

With waters of this type usually, even though a thorough removal of the carbon dioxide is effected by efficient aeration, it is necessary to supplement that step in the treatment by additional steps, as will be described later.

Organic Matter

Iron or manganese present in organic combinations is not removed by simple aeration and filtration. Coagulants fed into floc forming aggitating devices to accelerate floc formation and sedimentation tanks or basins must precede the filters.

Excessive Aeration

This has been known to interfere with the complete removal of iron and especially manganese. In such cases, restricting the aeration, i.e., limiting the absorption of the oxygen to a fraction of saturation, gives better results.

Types of Plants

Waters Low in CO_2 and Relatively Low in Iron Responding Readily to Oxidation

A small amount of air can be introduced by sniffling air into the suction side of the well pump for oxidation purposes. The well pump can then pump the oxidized water directly through either a single pressure filter or, to avoid frequent backwashings, through a coarse pressure filter followed by fine pressure filter direct to storage or use, thus making repumping unnecessary.

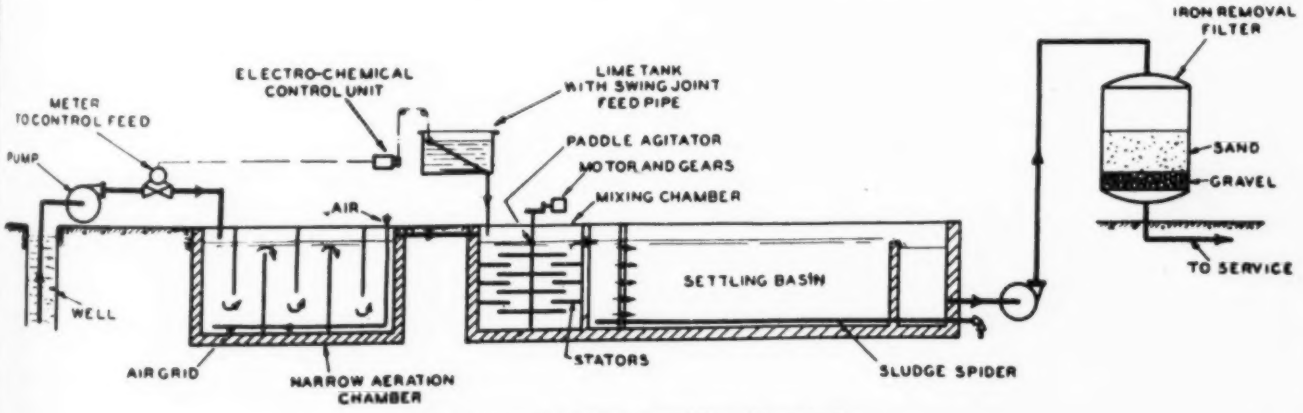
However, where preferred, gravity filters can be employed. Air wash systems should be employed where their use is deemed advisable.

Waters High in CO_2 Requiring CO_2 Removal by Alkali Feed or Efficient Aeration Before Final Filtration

In this case, the arrangement just described can be employed provided an alkali feed is installed to neutralize the CO_2. However, as air is free, if the quantity of water being pumped is appreciable, an efficient type of aerator should be installed, preferably either a coke tray type or degasifier bubbling type to insure exposing the water to the air in thin films or drops so that each particle of water contacts air low in CO_2 content. However, should the iron present in the raw water be very high, a sedimentation tank or basin may be required.

Waters of Low pH Value That Do Not Respond Readily to Oxidation

In such cases, following aeration, lime or soda ash is fed by means of a proportionating chemical feed to a sedimentation tank or basin (equipped with floc formers for aggitating purposes).

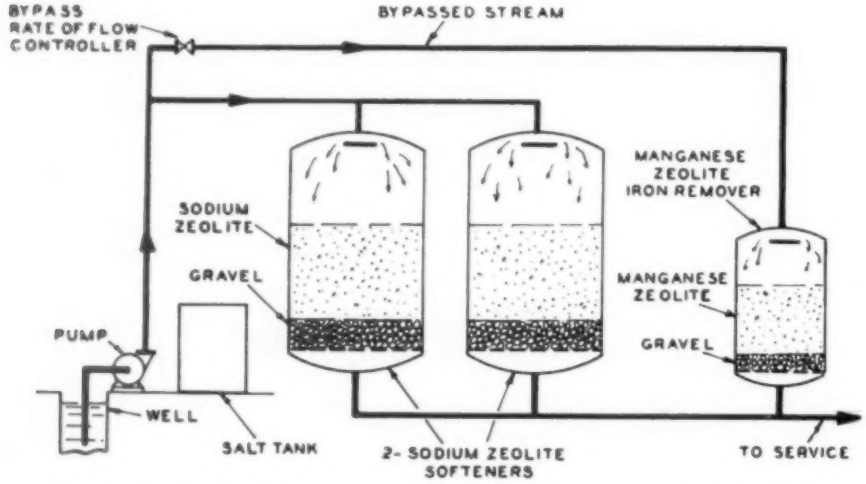


Iron Removal System Providing Flocculation.
Involving aeration, lime treatment, flocculation and clarification before filtration.

Lime is employed for the larger plants—soda ash for the smaller plants. Lime gives better results because it also has a coagulating effect. However, it also increases the hardness and as this is objectionable in many cases, soda ash is employed. The settled water is then pumped through filter equipment to either the mains direct or to storage and the mains.

Waters Containing Iron in Organic Combinations

The treatment suited to any given case of this kind will depend upon the type of organic compound present. The best treatment must be determined by experiments in the field and the laboratory. Further, the treating plant should be designed so that the pH values may be altered at will and also so that different coagulants may be added as required.



Combination Zeolite Softener and Manganese and Iron Removal Zeolite Units. Capable of producing iron free effluent of 4 to 5 grain hardness—favored in municipal installations.

Obviously, this will mean equipment for feeding various chemicals, sedimentation (and possibly double sedimentation) and filtration, plus chlorination.

Waters of Low Iron Content Where Reduction in Iron Content Should Be Below 0.1 ppm.

Manganese zeolite filters are most effective in the removal of iron where practically complete removal is desired for industrial purposes. Manganese zeolite consists of sodium zeolite treated by manganous chloride and oxidized by sodium or potassium permanganate. The manganese zeolite proper acts as an active carrier and catalytic reagent. The oxides themselves do the work of iron removal. These oxides give up oxygen to the water for the necessary oxidation reactions. They are re-oxidized by passing permanganate solution through the bed. Approximately 0.01 lb. of permanganate per thousand gallons is required for the average water. These filters are backwashed daily, but usually regenerated only at weekly intervals.

Sodium zeolite of the natural type, provided it has been correctly processed, or "Zeo-Karb" material, a carbonaceous zeolite, may be economically employed to remove iron and manganese by base exchange, at the same time that the zeolite is softening the water. When these types of zeolites are employed for iron and hardness removal by base exchange, the iron must be maintained in the *ferrous* form. Therefore,, well waters cannot be exposed to air before such zeolite treatment. The regeneration of units of this type is accomplished by the usual sodium chloride regeneration employed in zeolite softening.

Water Softening

There are five methods of water softening in general use. These are:

1. Zeolite Process—Sodium Cycle.
2. Zeolite Process—Hydrogen Cycle.
3. Cold Lime Soda Process.
4. Combination Lime Zeolite Process.
5. Hot Process.

Processes Nos. 1, 2 and 4 will reduce the hardness of the water to practically zero. Process No. 3, depending on the way it is carried out and also the composition of the raw water, will reduce the hardness from 3 to 5 grains per U. S. gallon. Process No. 5 will reduce the hardness to some figure below 1½ grains per U. S. gallon, depending upon the character of the water, the chemicals employed, etc.

Zeolite Process (Sodium Cycle)

With this method the hardness is removed by base exchange; the calcium and magnesium being retained by the zeolite while the corresponding sodium salts are found in the effluent. After the rated capacity of the zeolite to soften water to zero hardness has been exhausted, the softening capacity is restored by treating the zeolite with a solution of common salt.

As this salt solution comes in contact with the zeolite, the calcium and magnesium is removed in the form of the soluble chlorides, and its original sodium content is restored. After flushing the chlorides of calcium and magnesium, plus excess salt, to the drain, the zeolite is ready to soften a further equal quantity of the hard water.

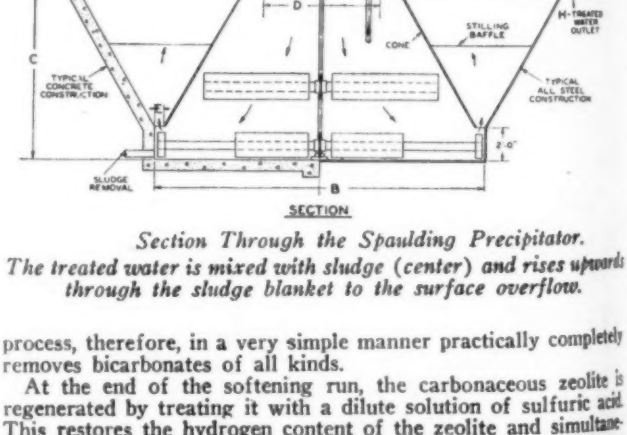
These alternate softening runs and regenerations can be repeated indefinitely, as the wear and tear on a correctly processed zeolite is negligible. Therefore, the annual cost of replacing this zeolite is correspondingly low. The effluent from a zeolite water softening plant is practically of zero hardness. As zero hardness water is either a requirement or at least desirable for most industrial processes, all of the water used in an industrial plant is usually passed through the zeolite plant. In the case of municipal zeolite plants, a zero hardness water is not required. Therefore, in such cases, enough hard water is bypassed and mixed with the zeolite softened water to yield a mixed effluent of the desired degree of hardness.

Zeolite water softeners are available to operate automatically through all cycles of operation by a combination of a motor driven multiport valve with electrical controls. Automatically, the equipment is cut out of service, backwashed, brined, rinsed and returned to service. About 90% of the more recent municipal zeolite water softening plants are of the automatic type.

Zeolite Process (Hydrogen Cycle)

In this process of water softening, a carbonaceous type of zeolite is employed. It is of especial value in softening waters of a high bicarbonate content, as the bicarbonates, of sodium, calcium, or magnesium, are replaced by carbon dioxide and water; the base being retained by the zeolite.

The carbon dioxide may then be removed by passing the softened water through a degasifier (bubbling) type of aerator. This process, therefore, in a very simple manner practically completely removes bicarbonates of all kinds.



Section Through the Spaulding Precipitator. The treated water is mixed with sludge (center) and rises upwards through the sludge blanket to the surface overflow.

At the end of the softening run, the carbonaceous zeolite is regenerated by treating it with a dilute solution of sulfuric acid. This restores the hydrogen content of the zeolite and simultaneously removes the bases in the form of soluble sulfates. These,

plus the excess of acid, are then flushed out to the drain, after which the zeolite is ready for the next softening cycle.

Cold Lime Soda Process

In this process, as carried out in the conventional type of equipment, the raw water is treated with regulated dosages of lime and soda ash. The bulk of the hardness precipitated by these chemicals, is then settled out in a settling tank having a detention period of at least 4 hours.

It is then either recarbonated and filtered or filtered and recarbonated. As usually carried out, the effluent so produced has a hardness of 5 grains per gallon.

In the relatively newer Spaulding Precipitator type of equipment, the treated water is brought into intimate contact with suspended sludge. This suspended sludge acts to produce a more stable effluent in a much shorter period of time.

In practice, it has been found that the Spaulding Precipitator requires only a one hour detention period and that the reduction of hardness is so complete that recarbonation is either carried out to a very slight extent or eliminated.

Combination Lime Zeolite Process

In the combination lime zeolite process of water softening, the bicarbonate hardness is reduced by treatment with lime. The lime treated water is then recarbonated, filtered and then passed through zeolite water softeners.

The net effect is that the lime treatment removes the bulk of the bicarbonate hardness and the subsequent zeolite treatment removes the non-carbonate hardness plus any residual bicarbonate hardness. In many cases, it has been found economical to employ this combination type of treatment because of the savings effected in the lower cost for salt vs. soda ash required per 1,000 grains of hardness removed.

For industrial processes or boiler water, all of the lime treated water is passed through the zeolite water softeners. Incidentally, when *any* water is used for boiler feed, it is important to give consideration to supplementary treatment so that the final reedwater will conform to modern power plant practice, as prescribed by the ASME. For municipal water supplies, only the requisite portion of lime treated water, required to produce a 4 to 5 grain per gallon hardness in the mixed effluent, is shunted through the zeolite water softening equipment and again joins the lime softened portion.

Hot Lime Soda Process

The hot lime soda process of water softening is carried out by adding carefully regulated dosages of lime, soda ash and/or other chemicals to the raw water, after heating it to a temperature at or near the boiling point. Since the high temperatures employed speed up the chemical reactions, a detention or settling period of only one hour is required. (This statement indicates the value of the Spaulding Precipitator which requires no heat input.)

The settled water is then filtered through filter beds of non-siliceous material. Depending on the excesses of chemicals used, the hardness of the effluent varies from as low as 1½ grain per gallon down to a fraction of a grain. As this process must be carried out hot, its application is obviously practically limited to the production of boiler feed waters.

* The content of this article is in part derived from a paper read by the author before the Michigan Section of A.W.W.A. and Michigan Conference on Water Purfication meeting jointly.

MUD-BALL AND HARD-SPOT BREAKER

By HOMER W. SCHUMPERT

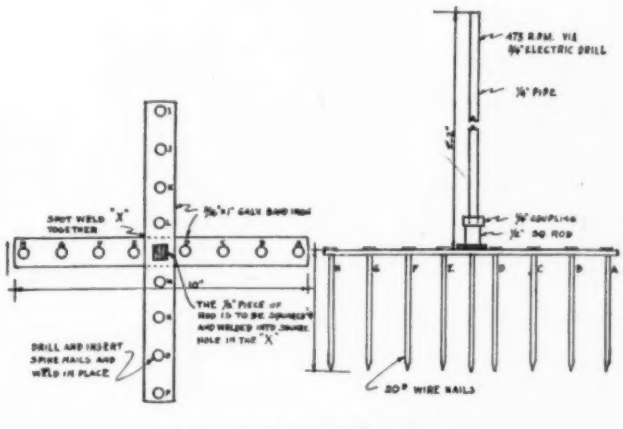
Superintendent of Water, Light and Sewage, Newberry, S. C.

Like many other plants, our filtration plant at Newberry has been troubled with mud-balls and hard-spots in the sand beds.

After trying many schemes and devices, that to be described seems to be of sufficient value to justify its publication.

The "Mud-Ball Breaker," as we call it, is here sketched. It is made from two 10-in. pieces of cross-arm bracing, for electric-line poles, welded in the form of a cross and attached to a shaft of ¼-in. steel pipe. The "tool" is turned by a light weight hand motor such as is used for electric hand-drills.

Through the pieces of bracing (1 in. wide by 10 in. long by 3/16 in. thick) are drilled holes to take 20-penny nails and a square hole (½ by 1.2 inches) is cut at the center of the cross (see sketch). The nails are welded in at their heads and the strips of bracing are spot-welded together at the center. A 2-in. piece of ½-in. steel rod is squared at the end and welded into the square center hole. A coupling and reducer connect the rod and the shaft of ¼-in. pipe. This shaft, 2 ft. long, fits into the chuck of the standard ¾-in. electric hand-drill which has a free-speed of 475 r.p.m.



Details of the Mud-Ball Breaker

Using the Filter Wash Tool

The water level is lowered in the filter until only 1 or 2 in. stands above the filter bed. Then the operator plugs in the cord of his tool (drill) and climbs down into the filter troughs. He starts the tool rotating at the 475 r.p.m. speed and proceeds to attack the mud-spots with it for about 6 minutes, employing a churning (up and down) motion of the whirling head. Then the filter is washed as usual.

We tried experiments thinking it possible to improve this device, but in the end we believe the sketched tool, as simple as it is, does the best job without the "improvements." When the spinning cross arms strike a wall the tool merely bounds away without damage. The whole assembly is light, inexpensive, and (most important) it does the job.

[Mr. Schumpert comments by letter: "If you do not believe that the job is easily and effectively done, then just try it yourself."—Ed.]

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MOTOR DRIVEN AND HYDRAULICALLY OPERATED MODELS.
MANUALLY ADJUSTABLE AND AUTOMATIC AND PROPORTIONAL UNITS.
DESIGNS FOR HIGH OR LOW PRESSURE.

Fig. 1

HEAVY DUTY CHEM-O-FEEDER
0-7 gal./hr.
0-100 lbs./sq. in.

Fig. 2

DUPLEX DELUXE CHEM-O-FEEDER
0-16 gal./hr.
0-100 lbs./sq. in.

Fig. 3

TRIPLEX MULTI-CONTROL
0-21 gal./hr.
0-100 lbs./sq. in.

Fig. 4

HIGH PRESSURE MIDGET CHEM-O-FEEDER
0-6.5 gal./hr.
30-200 lbs./sq. in.

Fig. 5

LOW PRESSURE AUTOMATIC AND PROPORTIONAL CHEM-O-FEEDER
0-5 gal./hr.
4-100 lbs./sq. in.

Fig. 6

HIGH PRESSURE AUTOMATIC AND PROPORTIONAL CHEM-O-FEEDER
0-5 gal./hr.
30-200 lbs./sq. in.

Any water or sewage treatment chemical can be handled with any of these feeders. All are equipped with molded transparent plastic reagent heads. All have adjustable stroke lengths. Figures 1, 2, 3, and 4 have adjustable stroking rate and all but Figures 3 and 4 are adjustable while operating.

Additional standard feeders of capacity from 3.5 gal./hr. to 2600 gallons per hour are manufactured in motor-driven and meter controlled models for pressures from less than atmospheric to 6000 lbs./sq. in. Bring your proportioning problems to:

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Chemical Feeder Headquarters

WATER SOFTENING*

With Particular Reference to Its Economic Aspects

By CHAS. P. HOOVER

Superintendent of Purification

Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

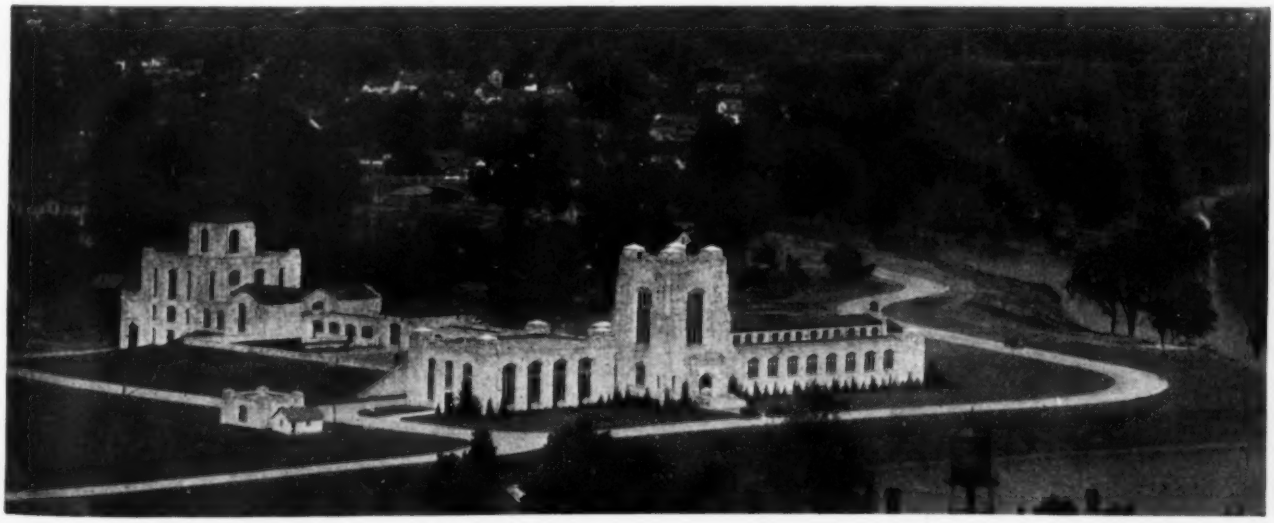
Economic Aspects of Water Softening

The water supply in a large number of cities and villages should be softened because:

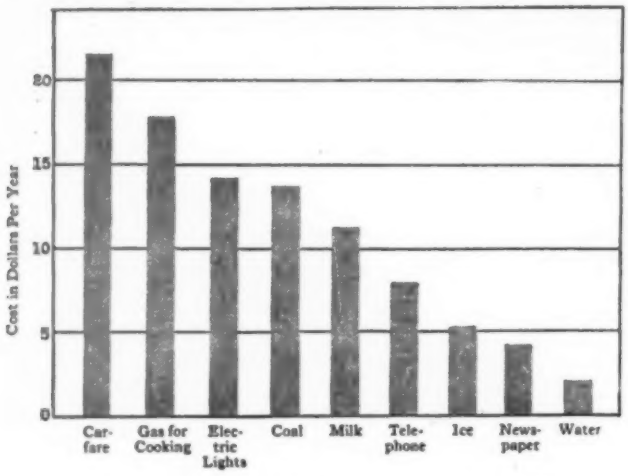
1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

* Excerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.



The Water Softening Plant of Fort Wayne, Indiana



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons = 2 + 0.2H).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196,133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.59

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

[2]Geological Survey of Ohio, Bulletin 29, 1925.

[3]Report of Water Commission, 1922.

[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

The results show.

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stunts Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

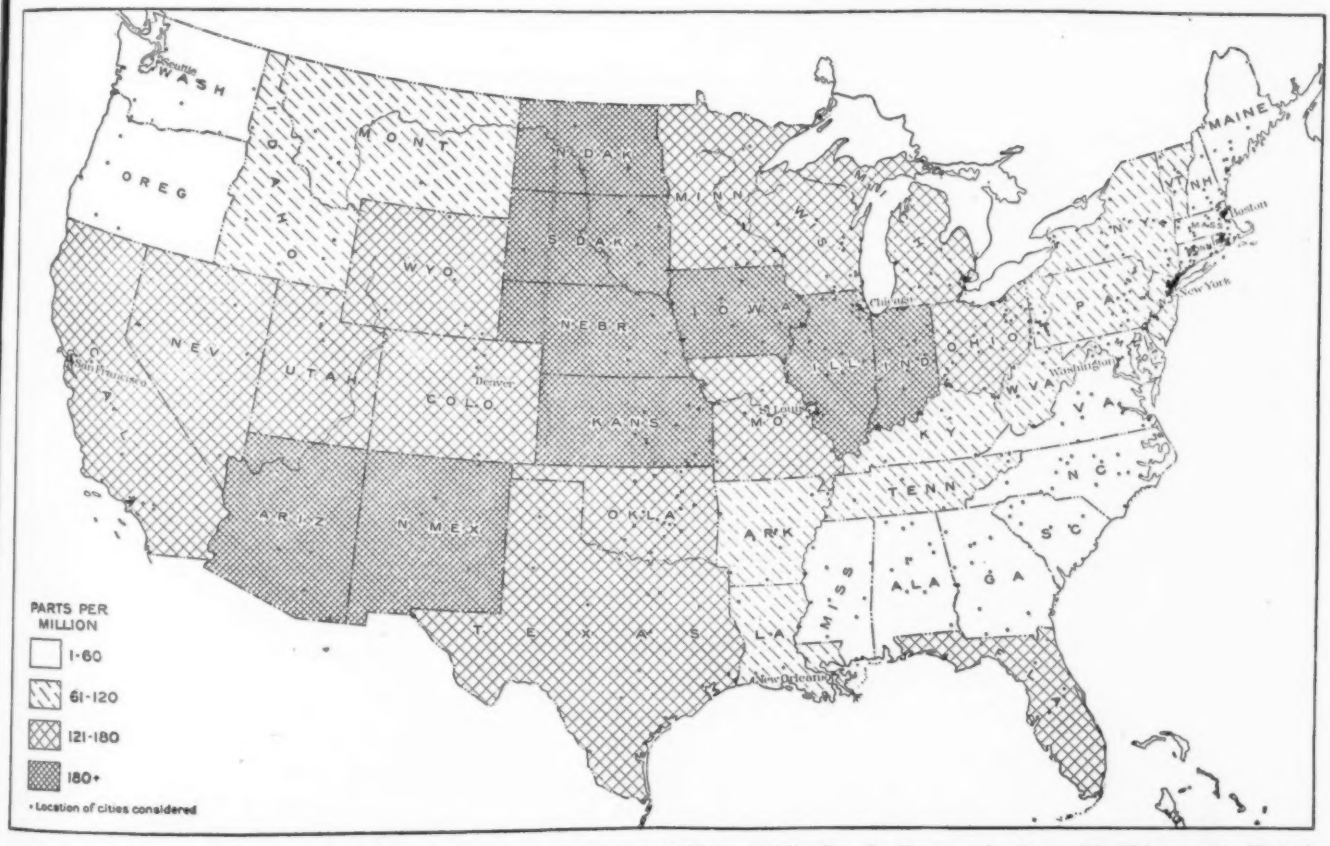
Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5] U. S. Bureau of Mines, Tech. Paper 218.
[6] Bulletin, American Railway Engineering Association, November, 1923.
[7] Alvord, Burdick & Howson (Chicago), a private communication.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

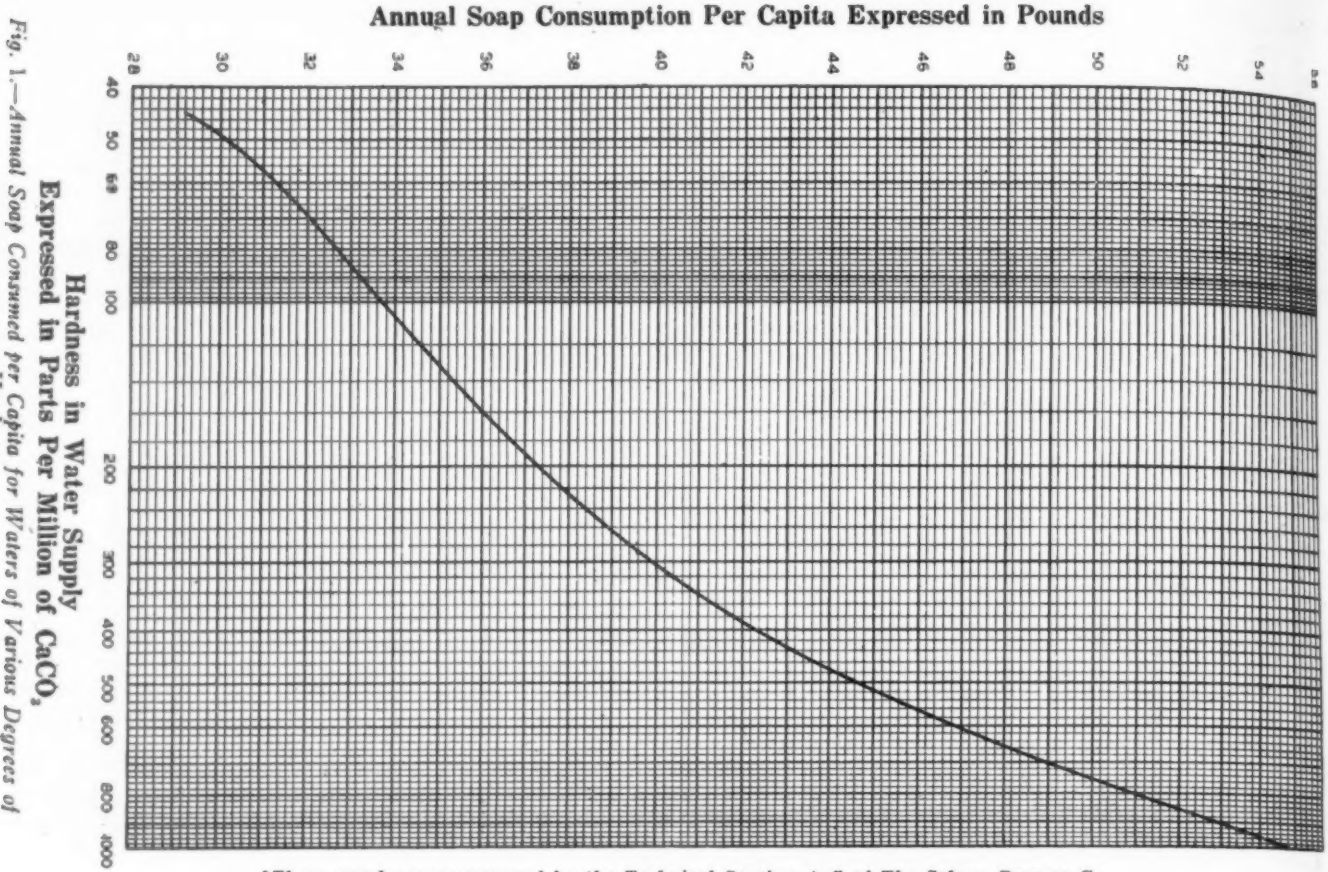

Annual Soap Consumption Per Capita Expressed in Pounds
28 30 32 34 36 38 40 42 44 46 48 50 52 54
Hardness in Water Supply
Expressed in Parts Per Million of $CaCO_3$
40 50 60 80 100 200 300 400 500 600 800 1000

Fig. 1.—Annual Soap Consumed per Capita for Waters of Various Degrees of Hardness

[These graphs were prepared by the Technical Service staff of The Solvay Process Co. from soap consumption data compiled by H. W. Hudson and published in the A.W.W.A. Journal—Vol. 25, p. 645, 1933. These graphs and other valuable information on water treatment appear in Solvay's Technical Bulletin No. 8.]

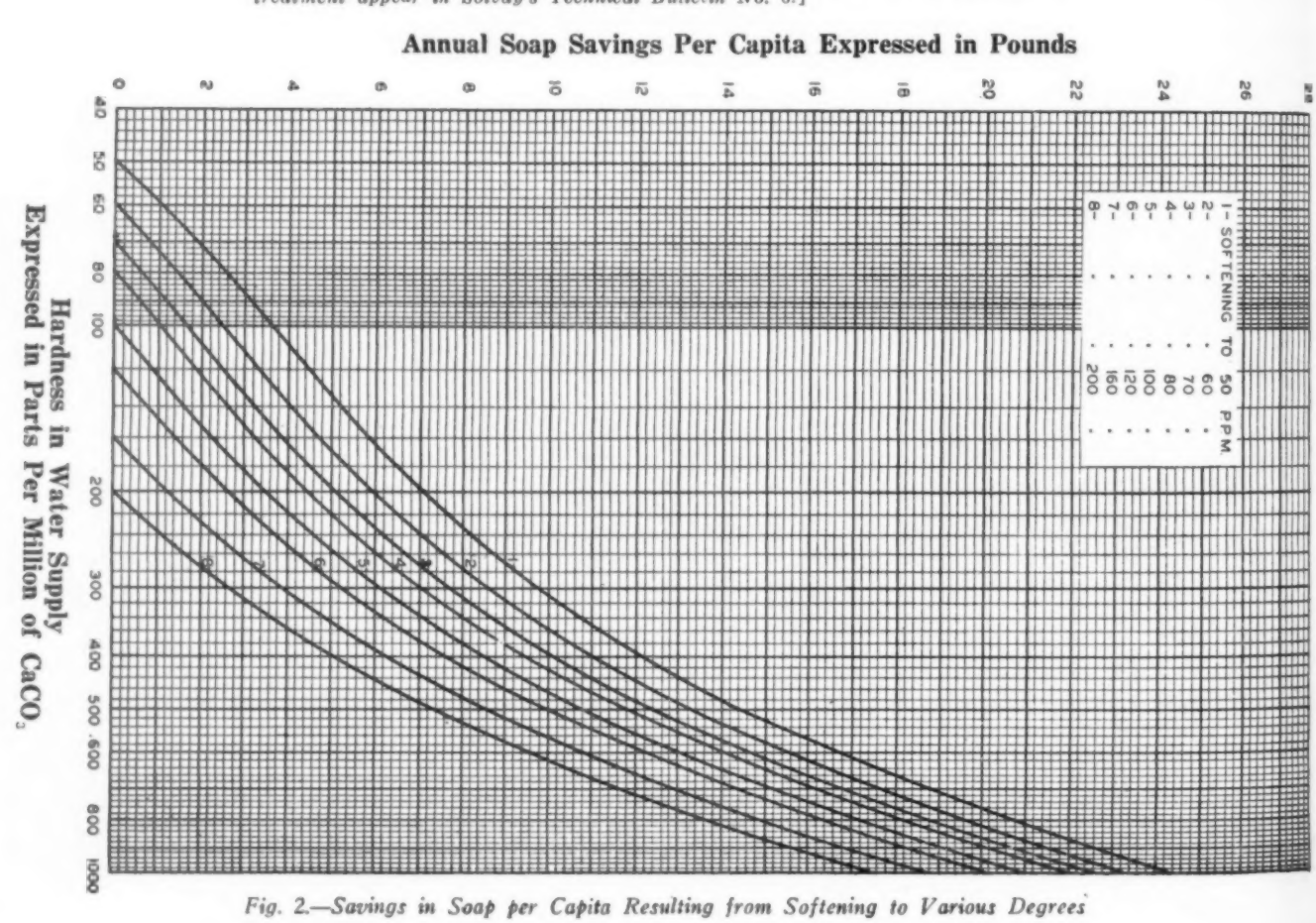

Annual Soap Savings Per Capita Expressed in Pounds
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Hardness in Water Supply
Expressed in Parts Per Million of $CaCO_3$
40 50 60 80 100 200 300 400 500 600 800 1000
1- SOFTENING TO 50 PPM
2- 60
3- 70
4- 80
5- 100
6- 120
7- 160
8- 200

Fig. 2.—Savings in Soap per Capita Resulting from Softening to Various Degrees

USE OF INHIBITORS IN CLEANING METALLIC PIPE

By ALLEN ABRAMS* and C. L. WAGNER*
Rothschild, Wis.

WATER pipes in certain sections of the country are likely to become clogged by corrosion or deposits from the water. In many cases this has reqired replacement of the pipes, a procedure which is often costly due to the necessity of tearing out walls and floors. As a result there have been attempts to clean pipes by the use of muriatic or other acids with the intent to leave the acid in just long enough to remove the scale and yet not long enough to attack the pipe itself. This, however, is a questionable expedient and may be more expensive than the replacement of the pipes.

During the last decade considerable interest has been shown in the use of inhibitors in pipe cleaning operations involving acid treatment. These are usually nitrogenous materials such as aniline or pyridine; and, even glue and flour have been used. When small quantities of such substances are added to an acid solution the resultant mixture will attack rust or scale but will have practically no effect on the pure metal itself. Wide use has therefore been made of this principle in the acid process of "pickling" metals to effectively remove scale while rendering the loss of metal underneath almost negligible.

An example is also given of the use of this principle in cleaning the pipes of a thirty-five story office building located in downtown New York.**

Many of the pipes were concealed behind expensive marble walls and it was estimated that it would cost between $100,000 and $300,000 to replace this piping, not to mention the serious inconvenience to tenants. By the use of an acid-inhibitor combination the whole cleaning operation was carried out on Saturday afternoon without inconvenience to the tenants. The pipes were returned to practically their normal condition of carrying capacities and the cost of the operation was but nominal.

This method attracted our attention in 1927 and we made initial tests to determine how effectively inhibitors would reduce the action of acid on the metal. In parallel tests on galvanized iron pipes 16 per cent muriatic acid was used alone, to compare with the same acid containing 3 per cent of an inhibitor. Equal lengths of pipe were allowed to stand in each solution for six hours. At the end of that time the pipe in muriatic acid had lost 50 per cent of its weight while that in the inhibited acid had lost but 0.2 per cent of its weight. We were then satisfied that the inhibitors would effectively prevent destruction of the pipes by such acid when submerged for a relatively short period.

Working Demonstrations

Not long afterwards two lengths of pipe, leading from the basement of our main office to the second floor became filled with rust and other deposit, completely stopping the passage of steam. It would have been relatively expensive to replace this piping and we therefore opened the two lengths at the top and cleaned them by pouring in inhibited acid, allowing it to work its way through. One overnight treatment, followed by a thorough flushing was sufficient to clean these pipes and no further trouble was encountered.

Early this year the Marathon County Board decided that it would be necessary to tear out and replace all the water piping in the Mount View Sanatorium due to the fact that it was so stopped up that it was impossible to get an adequate water supply through the system. When the matter was brought to our attention we suggested that an attempt be made to clean several lengths of this pipe and a decision could then be made as to the further course to be pursued.

Twenty-five gallons of 14 per cent muriatic acid were treated with 3 per cent, by volume, of the inhibitor.*** The treated acid was placed in a barrel to which was connected the suction of a small rotary pump. The acid was then forced upward from the basement to the second floor through a length of one-inch pipe, thence through a cross-over and down through another length of pipe to the basement. The returning acid passed through a fine screen to remove any dislodged particles and thence to the solution barrel.

At the beginning of the test a considerable amount of solid material was dislodged from the pipes and it was almost impossible to force the acid through. The pipes were then opened on the second floor, the acid mixture was poured in and allowed to flow by gravity until the pipes were filled. The bottom openings were plugged, the acid allowed to stand for eight hours and the acid withdrawn and the pipes thoroughly flushed. Examination indicated that the scale had been practically completely removed.

Control Procedure

In order to determine how effectively the cleaning was being done, three 6-inch lengths were cut from a 1-inch pipe, which was so clogged with rust and dirt that it was barely possible to get a pencil into the opening. One of these pipes was retained without treatment and the other two were connected in the circuit through which the acid was being pumped. At the end of about two hours one length of pipe was removed and found to be almost completely clean except for small patches of rust on the walls. After ten hours the other length of pipe removed for examination proved to be entirely free of rust and scale and there was no apparent action on the metal itself.

In the cleaning operation approximately 2,800 feet of pipe were treated, ranging from ½ inch to 4 inches in diameter. Estimates by George Baumgardt, who was in charge of the plumbing work, showed that the total labor costs were $870, while the cost of acid and inhibitor was approximately $20—a total of $890. Mr. Baumgardt estimated that the cost of replacing the piping would have been:

Galvanized pipe fittings and valves	$1,000
Labor for installation	5,000
Plaster, concrete floor and repainting	2,500
Total	$8,500

*Department of Research and Development, Marathon Paper Mills Co., for which the senior author is Technical Director. Mr. Wagner is chemist.

**"Removing Rust from a System with Piping Acid," F. N. Speller, E. L. Chappell and R. P. Russell—Chem. and Met. Engineering, July, 1927.

***Inhibitors are available, from several of the larger chemical companies—Barrett & Co., Monsanto Chemical Co., General Chemical Co., et al.

Effect of Altitude on Pumps

When a pump is operated at elevations above sea level, the lower atmospheric pressures encountered have a double effect on the pump performance.

1. The lower atmospheric pressure cannot support as high a column of water so that the maximum practical suction lift decreases.

2. The lower atmospheric pressure reduces the horsepower output of the gas engine, thus causing it to lose speed which results in a loss of capacity and discharge head of the pump.

At elevations above sea level, the suction lift on the pump should be reduced accordingly to insure that the same amount of water can get into the pump as would get in at the equivalent sea level lift. The following table gives equivalent suction lifts for various elevations.

Altitudes	Suction Lifts in Feet			
Sea level	10	15	20	25
2,000 ft.	8.8	13.2	17.6	22
4,000 ft.	7.8	11.7	15.6	19.5
6,000 ft.	6.9	10.4	13.8	17.3
8,000 ft.	6.2	9.3	12.4	15.5
10,000 ft.	5.7	8.6	11.4	14.3

When a gas engine driven pump is operated at elevations of 4,000 ft. or over, the engine should be equipped with a high altitude head. However, even with a special cylinder head, there is still a power loss of approximately 3 per cent for every 1,000 ft. of elevation. This will result in a loss of speed, and a loss of pump performance. The following table gives the loss in performance that can be expected at various elevations.

Altitude	Percentage of Sea Level Discharge	Percentage of Sea Level Head
	Percent	
Sea level	100	100
2,000 ft.	97	95
4,000 ft.	95	91
6,000 ft.	93	87
8,000 ft.	91	83
10,000 ft.	88	78

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CORROSION CONTROL IN POTABLE WATER SYSTEMS

By ROLF ELIASSEN

Prof. of San. Engr., New York University

WATERWORKS engineers are faced with an extensive program of corrosion control in an effort to conserve the huge investment in ferrous metals encountered in water distribution systems and the services of consumers. The great quantities of water used, together with the demand for a low unit cost of water, have led to the search for an effective and economical means of corrosion control.

Research in the field of corrosion of metals has disclosed many of the basic factors which govern the electro-chemical phenomena involved. These researches have led to certain methods of control, many of which are applicable to industrial process waters where cost of prevention and potability are not governing factors. These methods include the use of corrosion resistant metals and alloys involving the elements of copper, nickel, silver, chromium, zinc, and others. Extensive use is also made of the lining of metal surfaces with glass, cement, enamel, plastics, rubber, and other organic materials. The addition of chemicals such as chromates to the water to induce passivity of the metal surface is also used in many industrial water systems.

Effect of Temperature

Temperature plays a vital role in the corrosion of ferrous metals. This is emphasized by the great number of repeated failures in domestic water heaters and tanks. West[1] has shown that in closed systems the rate of corrosion activity is about ten times as rapid at 180° F. as at 50° F. At 210° F. it is ten times the rate at 180° F. If the hot water systems are of the open type so that oxygen and carbon dioxide gases may escape to the atmosphere as the temperature rises, the change of corrosion activity assumes different characteristics. Friend[2] has shown that in an open system, despite the decrease in oxygen concentration with temperature rise, the rate of corrosion increases to a maximum near 176° F., after which it decreases until at the boiling point the rate is practically zero. Most of the domestic water systems in use throughout this country are of the closed type, with little opportunity for the release of dissolved gases. Many systems are uncontrolled to the extent that temperatures rise almost to the point of boiling. The need for additional research on the control of corrosion at the higher temperatures ranging between 150° F. and 200° F. is a vital one.

Dissolved Oxygen Removal

One of the most effective means of preventing corrosion is to remove the dissolved oxygen. Two practical methods of oxygen removal involving deaeration are commonly practiced. One method is to heat the water to a point just below boiling and vent the released gases to the atmosphere. At this temperature the solubility of gases in the water is virtually zero at atmospheric pressure. The cost of heating and subsequent cooling would be prohibitive for large systems.

The other method is to pass the water through an evacuated chamber, either with or without heat being added to the water. Vacuum deaeration could be accomplished without much additional cost at a treatment plant and would protect distribution mains as well as the pipes and equipment of the using agencies. This method of deaeration when practiced by the individual consumer, might involve repumping of the water. Economic studies would be necessary, to determine the applicability of these methods of oxygen removal.

Oxygen may also be removed by a process known as deactivation[3]. The water is passed over beds of scrap iron or steel to induce oxidation of the iron and concurrent deoxygenation of the water. Other reducing agents such as sodium sulphite can be used for deactivation. Further treatment is frequently required to remove suspended or colloidal material, thus involving additional expense which must be charged to corrosion control.

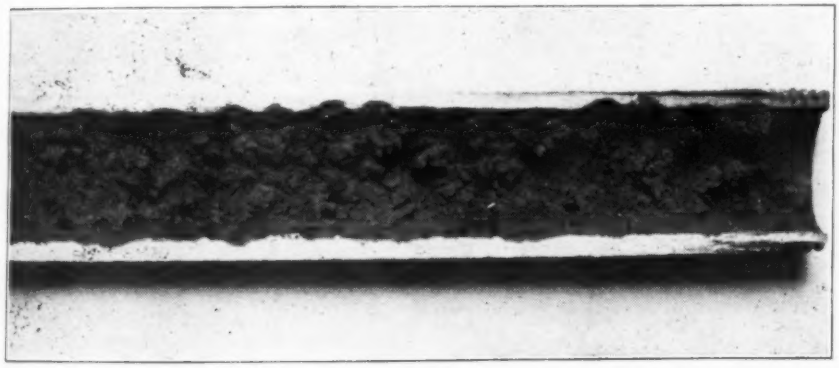
Protective Coatings

Some of the greatest possibilities for the economical solution of the corrosion problem will be found in the provision of protective coatings on the metallic surfaces in contact with the water. Some of the inexpensive coatings have been known to deteriorate with use and cannot be renewed. When this takes place the surface of the metal is exposed to the corrosive action of the water. Zinc coating of pipes, as in the galvanizing process, is typical of the coatings in this category. Other coatings, while they may last indefinitely, may be too expensive for adoption by the water works profession. The ideal coating should be economical and either durable or easily replaceable.

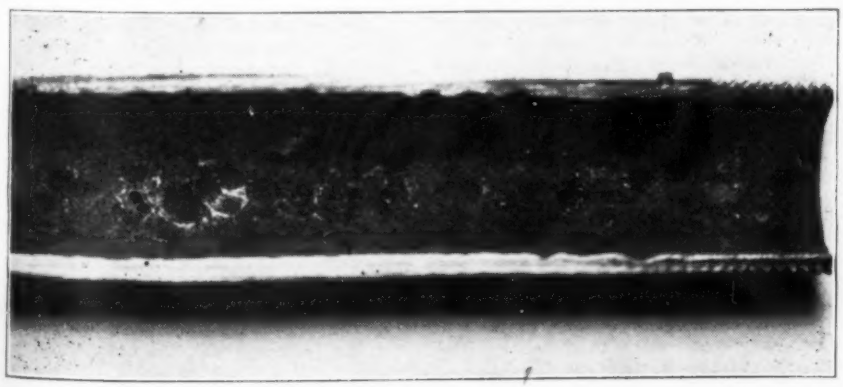
Many attempts have been made to form a calcium carbonate coating on metallic surfaces. This is most frequently accomplished by raising the pH with soda ash or lime. It must be emphasized that increase of pH alone will not assure protection against corrosion in the ranges of pH met with in potable water supplies. Wilson[4] has shown that pH has little influence on the rate of corrosion between the values of 5.0 and 11.5. In this range the concentration of dissolved oxygen in the water is the principal factor influencing corrosion.

Raising the pH may induce the formation of a calcium carbonate scale provided sufficient calcium and carbonate ions are present to form a precipitate. The saturation index of Langelier[5] and the stability index of Ryznar[6] are useful in determining the necessary dosages of chemicals to permit the precipitation of calcium carbonate. The mere existence, however, of conditions which would permit scale formation does not necessarily signify that a protective scale will be formed on the pipe. The indices do not take into account the rate of scale formation. Ryznar[6] states that the "index does not indicate how much calcium carbonate will deposit; whether a state of supersaturation will be present which will be great enough to produce a precipitate; and whether it is great enough to give a protective film."

It is conceivable that the rate of formation of tuberculated surfaces composed of the products of corrosion may be greater than the rate of formation of the coating



Tuberculation—Flow in Pipe Impeded, Usually Pitting Underneath



Pitting—The Result of Localized Corrosion

of precipitated calcium carbonate. In this case little protection will be afforded. Dangers are also inherent in the scaling of hot water heaters and other units in which the temperature of the water is raised. In their extensive studies on control of corrosion at Army posts, Kessler and his colleagues[7-8] have found that the porous nature of the calcium carbonate deposit permitted severe pitting and localized corrosion to take place under the coating. Thus, the value of this approach to corrosion control is open to question, more particularly in hot water systems than in cold water systems.

Research has been conducted by many experimenters with the goal of finding a chemical which might be added to the water in minute quantities to form a protective film over all metallic surfaces exposed to the water. The most important property of the desired chemical is that it shall have no effect on the potability of the water either from the physiological or the palatibility standpoints. The film or coating must be formed after the pipe is in place and be maintained by continuous or intermittent treatment of the water.

Sodium Silicate Films

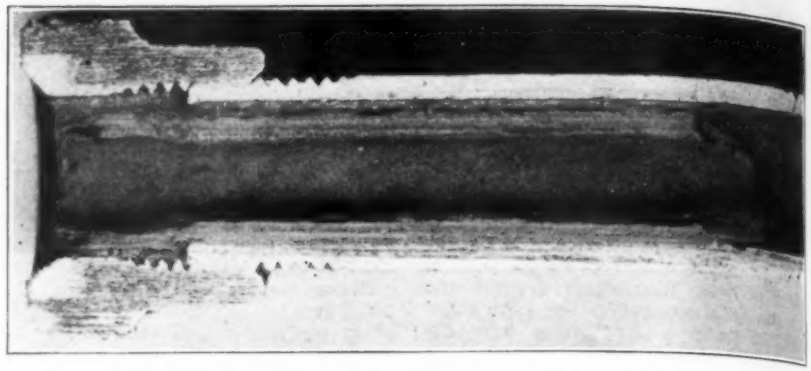
Sodium silicate was one of the first chemicals which research disclosed would be useful in controlling corrosion in potable water systems. Speller and his associates[9] carried out extensive work on the use of this chemical. Their experiments showed that 40 ppm. of SiO_2 would reduce corrosion by 85 per cent in a period of fifteen days with Pittsburgh water at 110° F. Many others have obtained similar results. Stericker[10] attributes the success of silicates to the formation of a film on the surface of the metal by interaction with the ferrous hydroxide formed as the ferrous ion leaves the metal. Formation of the film is usually a slow process requiring about a month in many waters.

It should be understood that control does not imply complete protection. Usually it involves a high percentage of decrease in the rate of corrosion and tuberculation. Vail[3] explains that the film is a slightly permeable gel and the transfer of oxygen from water to metal does not entirely cease with the formation of the film. The coatings, however, are usually evenly distributed, dense and adherent enough to retain the ferrous hydroxide concentration at the metallic surface sufficiently high to interfere with the passage of oxygen from the water to the metal. The presence of calcium or magnesium salts in the water is believed to facilitate the formation of the coating.

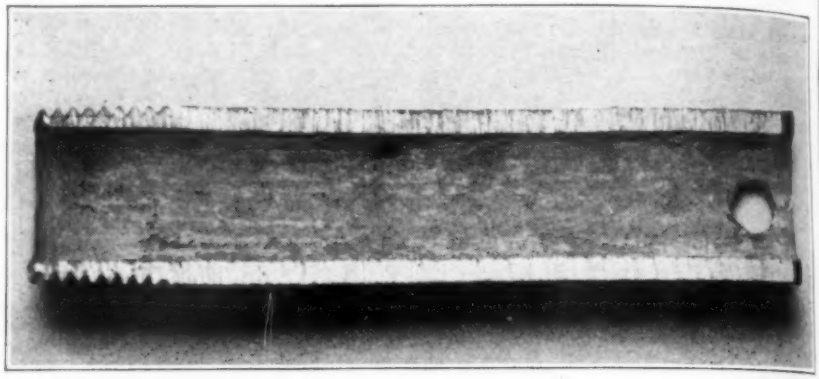
Experience at Army posts[8] has shown that sodium silicate can be relied upon to achieve corrosion control with many types of corrosive waters. For the average water, sodium silicate having the composition Na_2O: 3.25 SiO_2 and a specific gravity of 40° to 42° Baume' has been found most desirable. The pH of the water after addition of sodium silicate should lie between 8.0 and 10.6, the upper limit prescribed for potable water supplies by the U. S. Public Health Service[11]. If a pH of 8.0 cannot be attained by feeding the above silicate, it would be advisable to add a more alkaline silicate such as Na_2O: $2SiO_2$ or an alkaline compound such as soda ash or caustic soda along with the silicate.

Initial dosages should be in the order of 12 to 16 ppm. (as SiO_2), except in waters high in natural silica, in order to satisfy the high adsorptive demand of the metallic surfaces. After a month, or when a film starts forming in the remote parts of the distribution system, the dosage may be reduced gradually to the point where a residual of at least 1.0 ppm. above the natural silica content of the water can be detected in the far end of the distribution system. The mere presence of residual silicate is not enough to assure the formation of a coating, but the residual is necessary for the coating to be developed and retained.

Turbulent flow characteristics should prevail in the pipes in order to assure silicates being in contact with the pipe surfaces. Field observation of the metallic surfaces is essential to determine the degree of protection obtained. When the coating has formed, the final rate of feed may be reduced to a value as low as 4 to 8 ppm., or sufficient to maintain the coating at all times. Where water is heated to high temperatures, a greater dosage may be required.



Sealing—Too Much Coating—And Not the Right Kind



Protective Coating Stops Corrosive Action

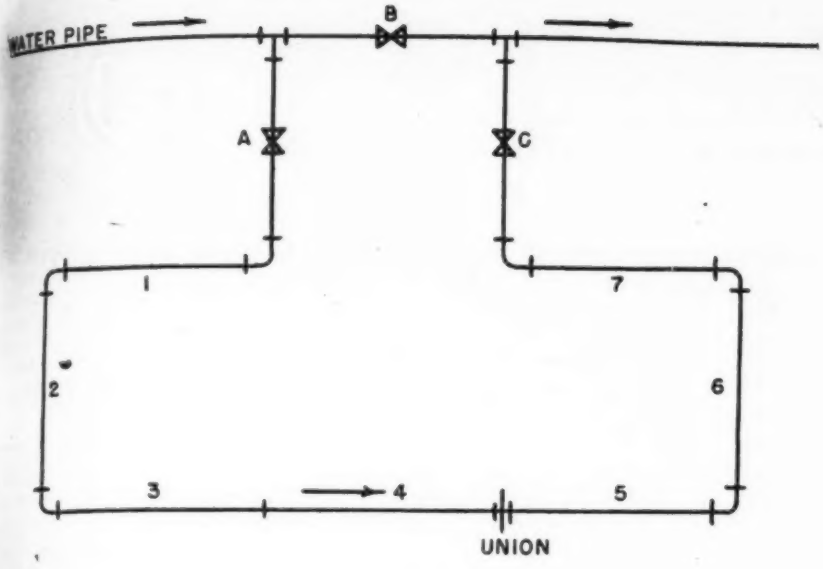
Polyphosphates as Inhibitors

Phosphates of certain types have been recognized as corrosion inhibitors during recent years. The phosphates most commonly used are the molecularly dehydrated polyphosphates known as sodium hexametaphosphate, $(NaPO_3)_6$, and sodium septaphosphate, $Na_9P_7O_{22}$. The formula for the latter may also be written as Na_2O: $(NaPO_3)_7$ showing that it is slightly more alkaline than the metaphosphate, but of similar composition. Hatch and Rice[13] claim that protection is achieved through the formation of a film on the metallic surface by adsorption of the metaphosphate from solution. Formation of the film does not take place rapidly, often taking a month to appear in the remote parts of the water system. It has been shown by Rice[12] that the results obtained will be proportional to the actual total quantity of metaphosphate passing over an area of metallic surface each day rather than the *concentration* of the chemical in the water. For this reason turbulent flow in the pipe is productive of best results.

Once the film is formed, reversion of the metaphosphate to orthophosphate takes place gradually. The latter is not effective in corrosion control. Sufficient metaphosphate must be present in the water to replace the orthophosphate which leaves the metal. The same holds true for the septaphosphates. Control of pH has not been found necessary as the chemicals have proven effective within the range of pH found in most natural waters, from pH 5.2 to 10.6.

As with silicates, the control is not usually perfect to the point of complete protection from corrosion, but the reduction in the rate of corrosion may be extremely high with many waters. This is verified by the report of the AWWA Committee on Water Conditioning Methods to Inhibit Corrosion[14]. After their exhaustive survey of this subject, their conclusions were, "In ferrous metal piping systems, the use of metaphosphates will nearly always eliminate, or at least minimize, the outward manifestations of corrosion, particularly red water and tuberculation." It should be emphasized that the absence of red water alone is not the criterion of corrosion control. Chemists have shown[14] that the polyphosphates will combine with the iron in the water to form soluble complex phosphate ions and thus mask the evidence of corrosion as far as the appearance of the water is concerned. To be considered successful the chemical must form a protective coating which will minimize the loss of metal from the surface in contact with the water.

The author and his associates have utilized the polyphosphates for corrosion control at many locations on the Atlantic and Pacific coasts where corrosive waters



TEST LOOP SHOWING
ARRANGEMENT OF SEVEN 12-INCH TEST PIPES

are prevalent. With steel piping it has been found desirable to start the feeding at a rate of from 6 to 12 ppm. of the polyphosphate. The higher value is necessary where water is heated to 185° F., which is the required temperature for disinfection of tableware. Tests by Morgen and Swoope[15] show that between pH 7 and 9 a good percentage of the polyphosphates may revert to orthophosphates in 24 hours.

As the film develops the dosage may be cut back to the point where sufficient polyphosphate is present in the water to give a residual of at least 0.5 ppm. of the meta- or septaphosphate at the far ends of the distribution system. In some instances the final dosage to secure effective control of corrosion may be as low as 2 ppm. in lines carrying cold water. More generally a dosage between 2 and 6 ppm. is required. Where maximum protection is necessary at 185° F. the ultimate feed may be even higher. Determination of minimum dosage depends upon residual metaphosphate present and observation of actual results on the metals in contact with the water.

Combination Treatments

Polyphosphates and silicates have been added together in some cases of corrosion control where feeding each chemical separately did not give the protection desired. This combination is particularly desirable where the water has a scaling tendency which will lead to clogging of pipes when silicate is used alone. Dosages would be somewhat less than for each chemical alone and can best be determined by experiment. The author has obtained good results using 2 to 4 ppm. phosphate and 8 to 12 ppm. silicate on corrosive waters.

Tetrasodium pyrophosphate has been used successfully in the mitigation of corrosion with dosages (anhydrous basis) similar to those employed with metaphosphates. Some authors[8] have reported on the use of a mixture of pyrophosphate and an organic material derived from the fermentation of certain plant juices. Sufficient experimental data and reports of field experience are not available on the use of either pyrophosphates or organic compounds to determine the conditions under which these chemicals can be used in the control of corrosion.

Proportional Feeding and Test Loops

Proportional feeding of the inhibiting chemicals plays an important part in the success of corrosion control. Hypochlorinators of various types have given excellent results in feeding solutions of phosphates and silicates. These feeders may be either the simple hydraulic displacement type for low flows or the plunger and diaphragm types for higher flows. Frequent cleaning and flushing is desirable in order to prevent clogging of the apparatus. Many other types of feeders can also be utilized, but solution feed at a rate proportional to the flow is recommended for most consistent results.

Test loops provide the most accurate means of checking on the sufficiency of protection obtained in hot and cold water services. It is essential that test pipes of typical metals used by water consumers be installed at critical points served by the water utility, particularly at the ends of the system remote from the point or points of chemical feed.

The accompanying diagram shows a simple layout which permits the pipes to be subjected to the actual conditions of temperature and flow characteristics encountered near the critical point at which protection is desired. The test pipes can be taken down at any time without interfering with the supply of water. As many test pieces as desired can be installed in a loop of this type. The important factor is the periodic observation of the coating developed and the degree to which pitting and tuberculation are arrested. Determination of minimum dosage can only be made by frequent observation and analysis of these test pieces. At the present time there is no other economical method as effective as this easily comprehended scheme in guiding the water works operator in the selection of the treatment or the amount and type of chemical to be used for the control of corrosion at any point in the water system.

Summary

On the basis of experience with many corrosive waters, the author believes that the accompanying table summarizes the average trend of chemical feeds which have given good results. Specific cases may vary appreciably from these average values. Actual control of chemical feed for any particular system must be based upon chemical tests of the water to determine the residual concentrations of the effectual chemicals at the ends of the distribution system. These residuals must be correlated with observations of results on the pipes themselves as evidenced by the examination of test pipes located at critical points in the system.

Remarkable strides have been made in this relatively new approach to the corrosion control problem. Extensive research and correlation of experimental data and field observation still remain to be accomplished before a satisfactory solution can be found for the protection of metallic surfaces in contact with water of any specific chemical makeup. Sanitary engineers should follow closely the development of new compounds for the possibility of application toward the solution of this problem. Analysis of the many different and unusual properties of the newly discovered silica-organic compounds, the silicones, may lead to one or more compounds which will give more positive control than presently obtainable with phosphates or silicates. The goal for which the waterworks profession is striving is the exact answer to the question of how much of what chemicals must be added to any specific water to assure control of corrosion in a particular water system.

Chemical Dosage for Corrosion Control

Chemical	Basis of Analysis	Dosage Initial ppm.	Dosage Final ppm.	Minimum Residual ppm.	Treated Water pH Min.	Treated Water pH Max.
Sodium silicate	SiO_2	12-16	4-8	1.0	8.0	10.6
Sodium hexametaphosphate	$(NaPO_3)_6$	6-12	2-6	0.5	5.2	10.6
Sodium septaphosphate	$Na_5P_7O_{20}$	6-12	2-6	0.5	5.2	10.6
Tetrasodium pyrophosphate	$Na_4P_2O_7$	6-12	2-6	0.5	5.2	10.6

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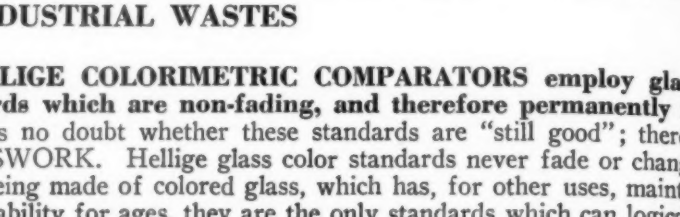
HELLIGE COLORIMETRIC COMPARATORS employ glass color standards which are non-fading, and therefore permanently reliable. There is no doubt whether these standards are "still good"; there is NO GUESSWORK. Hellige glass color standards never fade or change, never fail. Being made of colored glass, which has, for other uses, maintained its color stability for ages, they are the only standards which can logically carry a lifetime guarantee of accuracy. Glass standards are economical: bought once, they serve for practically an unlimited period, and thus quickly pay for themselves by the saving of time, chemicals, replacement cost, and other expenses encountered in the use of liquid standards. The standards occupy a minimum of space, and are the easiest to manipulate.



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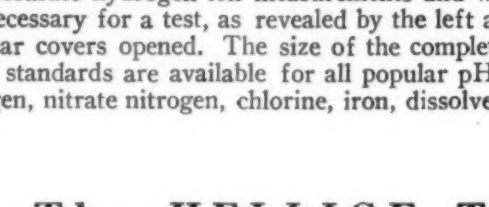

Illustrations show the observation fields: the one in the center shows the balanced field, after the proper adjustment of the slit by means of the drum knob; the end ones show the unbalanced fields.

This apparatus is based on the comparison of the Tyndall effect on the test liquid with a beam of light passing through the same suspension. Therefore, the use of standard suspensions which are tedious to prepare, and do not retain their original value, is entirely overcome. The comparison fields are distinctly differential so that measurements can be made with utmost convenience, simplicity, and speed, and correct results are obtained by anybody without special training for this type of work. Tubes of different liquid depths are available for turbidity measurements from 0 to 150 p.p.m. SiO_2, and sulfate determinations from 0 to 100 p.p.m. SO_4.

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DIRECT READING ARSENITE-ORTHOTOLIDINE TEST

In Which Interference Readings May Also Be Utilized

By A. A. HIRSCH*
State Department of Education, Baton Rouge, La.

IT IS well known that the orthotolidine test for residual chlorine is subject to false coloration and consequent error in the presence of nitrites, and oxidized manganese. These effects can be avoided, however, by auxiliary use of sodium arsenite solution, according to a method developed by Hallinan.[1]

Sodium arsenite, introduced before the orthotolidine reagent, prevents color formation by chlorine and chloramines, but does not inhibit false colors caused by interfering substances. Therefore, by noting the magnitude of the interference, or by an equivalent arrangement of the liquid cells in a comparator, a suitable correction can be applied in order to obtain the true residual representing chlorine and chloramines together.

When the sodium arsenite solution is added immediately following the flash color produced by free chlorine with orthotolidine, the slowly developing color representing chloramine residual is blocked. Evaluation of chloramines may then be made subtracting the value of free chlorine, i.e., the "flash" value, from the five-minute reading taken with orthotolidine in the usual way.

In a variation of this test proposed by Griffin[2] the corresponding false color in an arsenited orthotolidine mixture is subtracted from the flash and the five-minute readings of a conventional orthotolidine test to determine the free chlorine and the total chlorine, respectively. This paper presents a slightly modified reagent,[1, 3] a simplification of procedure to enable a full set of observations from a single comparator setup, and[3] demonstrates certain by-product values that the interference, itself, yields.

Sodium Arsenite Reagent Characteristics

In previous directions[1] a 0.5 per cent solution of sodium arsenite in distilled water is specified for use in the proportion of 0.75 ml. of solution per 15 ml. sample cell volume. Due to alkaline hydrolysis such a solution has a pH value exceeding 10.0, in which condition, according to Kolthoff and Sandell,[3] the arsenite is slowly oxidized to arsenate by contact with air, thereby reducing its strength some slight amount. Also, since orthotolidine is primarily an oxidation-reduction indicator, the presence of arsenate might be expected to cause false coloration by the very reagent which is expected to permit correction for interferences.

In order to test this possibility a 0.5 per cent solution of sodium arsenite in distilled water was aerated, and tested with orthotolidine at intervals. At the end of two hours' aeration the orthotolidine test produced a slowly forming color, equivalent to about 0.02 ppm. chlorine on 10 minutes' standing, and 0.06 ppm. as chlorine in half an hour. A four-day-old solution of sodium arsenite also gave a small false residual. Strangely, this effect is not due to the formation of sodium arsenate because a 0.5 per cent sodium arsenate ($Na_2HAsO_4.7H_2O$) solution did not form a color with orthotolidine reagent.

From these observations no explanation for the mechanism of threshold interference through the sodium arsenite itself is ventured, except to note its occurrence as a fact.

Preparation of Sodium Arsenite Reagent

In order to prevent the oxidation of sodium arsenite on long standing, the solution should be neutralized or slightly acidified.[3] After this precaution was taken, experimental aeration of the solution did not cause a false color to form when tested with orthotolidine.

Additional advantages of a slightly acidified solution are the prevention of a silicious precipitate from the glass container and the maintenance of a full acid reserve of the orthotolidine reagent to stabilize the pH value of the reaction mixture for optimum color characteristics. In a test on tap water (alkalinity 140 ppm. pH 7.8) neutralized sodium arsenite solution permitted a slightly faster rate of color development from interference than did alkaline sodium arsenite solution.

A doubling of the sodium arsenite concentration is advisable to minimize dilution errors when using arsenited samples as a blank. In a 15 ml. comparator cell, the error caused by 0.75 ml. of arsenite solution, as previously recommended,[1] is 5 per cent, which figure may limit accuracy of readings in the range of good color discrimination.

To prepare the sodium arsenite reagent, dissolve 10 g. of sodium metarsenite ($NaAsO_2$ mol. wt. 129.93) in 900 ml. of distilled water; neutralize with hydrochloric acid to the methyl orange end point, using the indicator externally on a drop plate, and dilute to a liter with distilled water.

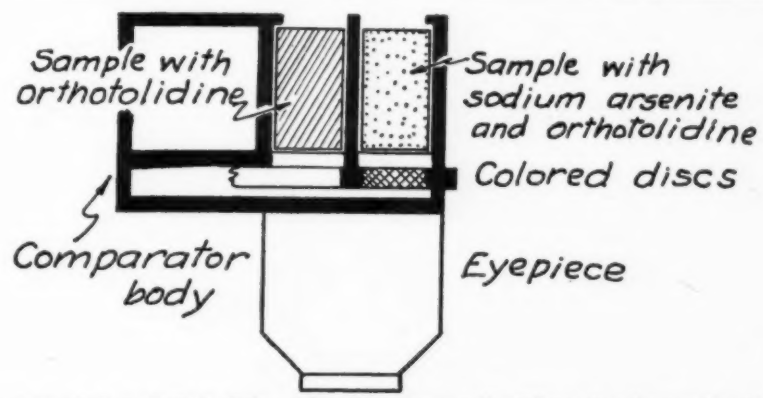
Simplified Procedure for Comparator Test

This technique is based on the repression of color by sodium arsenite, except for the interferences, and the differential development of free chlorine and chloramine residuals. Directions are stated for a popular comparator which holds a 15 ml. sample volume, but the proportions apply, in proportion, for other instruments.

Referring to the accompanying figure: In the left hand cell place the regular orthotolidine test mixture, consisting of 15 ml. of water sample and 1 dropperful (approximately 0.75 ml.) of orthotolidine reagent.[4] Instead of untreated water in the compensation cell to the right, in line of sight with the graded series of colored discs, place the inhibited mixture consisting of 15 ml. of water well mixed with one-half dropperful (approximately 0.38 ml.) of sodium arsenite solution; next add one dropperful of orthotolidine. This cell is best prepared first so that attention is freed for quick introduction, mixture and flash reading of the straight orthotolidine cell at the left.

The flash reading, taken within ten seconds, gives the free chlorine concentration directly, with instrumental correction, for

Reading time	Color Representations		Interpretation of disc reading
Immediate	Free chlorine Rapid Interferences	Rapid Interferences	Free chlorine
5 minutes	Free chlorine Chloramines Interferences	Interferences	Free chlorine and chloramines



Arrangement of Test Cells in Colored Disc Comparator for Direct Readings with Sodium Arsenite-Orthotoldine for True Chlorine and Chlorine Compound Residuals

*Director, Sectional School on Water Supply and Sewage Treatment.

TABLE I

Partial Results of Arsenite-Orthotolidine Tests at Lake Charles, La., Activated Sludge Plant to Show Effect of Nitrites

Liquor	Corrected Chlorine Residuals ppm.		Interferences ppm.	
	Flash	Five Min.	Immediate	Five Min.
Final settling tank effluent (before chlorination)	0	0	0.06	0.11
Plant effluent after chlorination—				
As formerly controlled with orthotolidine test	0	0	0.07	0.12
After raising chlorine dosage	0.04	0.07	0.08	0.11

rapidly forming interferences. After waiting for five minutes, a similar reading shows the total chlorine, both free and combined, likewise corrected for corresponding delayed false colors. Chloramine chlorine is calculated by difference between total chlorine and free chlorine.

To evaluate the interferences the arsenited mixture is moved into the comparator space to the left, and matched with the discs. Ordinarily, for this part of the procedure an untreated sample in the right hand position is unnecessary, unless the specimen is turbid or has natural color.

For assurance of full color development in all cells, the temperature of the samples should not be lower than 70° F. Free chlorine residuals flash color as low as 40° F., but if the water is chilled near the freezing point, this reaction also is retarded.

An analagous arrangement may be set up in the solution-standard-rack type of comparator by replacing the blanks for untreated water sample with arsenited-orthotolidine mixtures.

Applications

The direct reading arsenite-orthotolidine test appears to have a number of applications. The following discussion sets forth several situations in which this test does now or may find applications.

As previously indicated, the sodium arsenite protected orthotilidine test is useful and sometimes indispensable, whenever significant amounts of manganese, iron or nitrites are present in the sample.

In well water supplies, high in iron or manganese, the indicated residual by the conventional orthotolidine method is always erroneously high in samples taken close to the point of chlorination. Further out in the system, after these minerals have precipitated, the interference disappears.

In iron removal plants in which chlorine is used as the oxidant, the residual reading in the early stages of coagulation is too high due to interference of ferric iron still trailing in solution. This reading is important, since the control of chlorination is frequently based on it. Manganese behaves similarly.

Nitrites are likely to interfere in the chlorination of remotely polluted surface supplies, and in the effluent from filter beds containing certain nitrifying bacteria, especially when the raw water is high in ammonia or is given chloramine treatment prior to filtration.

Paramount interest lies in the control of chlorination in sewage treatment plant effluents from activated sludge or trickling filter units. Here the nitrites are sufficiently high to form a completely deceptive color following a low marginal chlorination, as frequently used. This *exact color* may also form with the *unchlorinated* final settling tank effluent. A real chlorine color is obtained only when the dose is boosted sufficiently, and controlled by the arsenite-orthotolidine method.

The close agreement between simple orthotolidine coloration in unchlorinated effluent and the arsenite-orthotolidine color in the same liquor following light chlorination constitutes assuring proof of the validity and the value of the arsenited test. Without correction for interference, the orthotolidine test for control of chlorination of sewage treatment effluents and nitrogenous trade wastes may be utterly worthless. A partial tabulation of results obtained in a study at the Lake Charles, La., sewage treatment plant, of interest in this connection, is given in Table I.

Utilizing the False Residual Values

While interferences are detrimental to the accuracy of the uncorrected orthotolidine test, they still are useful as rough or crude measures of the causative substances. Interferences may be measured in the arsenite-treated sample followed by orthotolidine, as described in the procedure.

In iron removal plants, the presence of unstable ferric ions is demonstrable only near the inlet of the settling basins; this fact may be taken as evidence of efficient oxidation. Persistent false color through an otherwise satisfactory plant may point to the concurrent presence of manganese slowly oxidizing at sub-optimum pH values. Disappearance of interferences in the distribution system is associated with deposits of iron or manganese in the mains. Table II shows such a succession of values obtained at the Lake Charles water treatment plant and distribution system.

Nitrite interferences are highly useful in following the degree of oxidation through the course of secondary treatment units and in the quick evaluation of effluents. An appreciable interference is expected in a well functioning disposal plant employing secondary treatment. Preliminary tests at the Lake Charles activated sludge plant seemed to enable correlation between satisfactory operation and the strength of the false residual.

Summary

This paper proposes that sodium arsenite solution be mildly acidified: (1) to prevent a possible trace of false residual due to unexplained oxidation, (2) to avoid silicious deposits from common glass bottles, and (3) to maintain the original acid reserve in the orthotolidine reagent to buffer the color reaction. It is proposed that the concentration of sodium arsenite be doubled to reduce the dilution error to a negligible amount.

It is also proposed that the sodium arsenite-orthotolidine test be used instrumentally to yield direct readings for free chlorine, total chlorine (both free and combined), and interferences in a single set of determinations.

It is also believed that interferences may be serviceable in themselves as a by-product of the test; the iron and manganese error may be used to observe their removal in a treatment plant, and the nitrite error may be used in evaluating quality of sewage plant effluents.

References

[1]Hallinan, F. J. Tests for Active Residual Chlorine and Chloramine in Water. *Jour. A.W.W.A.*, 36, 296 (1944).

[2]Griffin, A. E. The Practice and Control of Break-Point Chlorination. *Technical Publication No.* 213. Wallace & Tiernan Co., Inc., Newark, N. J. (1944).

[3]Kolthoff, I. M., and Sandell, E. B. Textbook on Quantitative Inorganic Analysis, p. 561. The Macmillan Co., New York (1936).

[4]Committee Report. Control of Chlorination. *Jour. A.W.W.A.*, 35, 1315 (1943).

TABLE II

Arsenite-orthotolidine Tests at Lake Charles, La., Water Treatment Plant to Show Effects of Iron Removal and Subsequent Ammoniation

Sample		Corrected Chlorine Residuals		Interferences	
		Flash	Five Min.	Flash	Five Min.
	ppm.	ppm.	ppm.	ppm.	ppm.
Mixed wells		0	0	0	0
Fe	2.8				
Mn	0.45				
Alkalinity	138				
CO_2	28				
pH	6.9				
Settling basin influent (after chlorination 4 ppm. and aeration)		0.90	0.90	0.06	0.13
Settling basin effluent		0.80	0.80	0.11	0.14
Filter influent (after 0.7 ppm. ammonia added)		0.40	0.80	0.11	0.13
Filter effluent		0.22	0.70	0.06	0.07
	ppm.				
Clear well		0.30	0.70	0.03	0.04
Fe	0.15				
Mn	0.07				
Alkalinity	130				
pH	8.0				
Distribution System—					
Eastward—					
¼ mile		0.27	0.80	0.03	0.03
¾ mile		0.07	0.10	trace	trace
1¼ mile		trace	0.03	0	0
Southward—					
½ mile		0.25	0.60	0.01	0.02
1 mile		0.17	0.42	0.02	0.02
1¼ mile		0.06	0.16	0	0
1½ mile		0	0	trace	trace

ENSLOW CONTINUOUS STABILITY INDICATOR

By ROBERT S. PHILLIPS, Chief Chemist
Water and Sewerage Department, Durham, North Carolina

OUR laboratory, like many another throughout the country, was extremely interested in the "Convention-Floor" invention of Linn H. Enslow, editor of WATER WORKS AND SEWERAGE, which has come to be known as the Enslow Continuous Stability Indicator or Enslow Stabilizer. This instrument, streamlining the so-called "Marble Test," seemed to be the answer to the water works operator's need for a practical short-cut to determine the proper treatment to attain the equilibrium point of finished waters. With certain modifications, explained later in this article, this instrument has been, and is, able to accomplish all its inventor originally hoped for.

Following publication[1] of early designs, we constructed a Stabilizer similar to that suggested. We soon discovered, however, that fine Calcium Carbonate did not behave according to our preconceived notions. Explained simply: if water velocities in the Stabilizer were high enough to suspend the chalk, fine Calcium Carbonate would carry over into the Stabilizer effluent, if velocities were low enough to obtain a clear effluent, "packing" and consequent short-circuiting of the chalk resulted.

The problem, therefore, was one of finding a closed device which could be added to the system and which would provide an adequate contact period with the fine calcium carbonate without sweeping over chalk. In other words, a container was needed which would provide for both high and low water velocities under constant flow conditions. A conical vessel, having a relatively small cross-sectional area at its vertex and a large area at its base, would solve the problem, it was thought, if the water was introduced at the vertex. This idea was based on the same principle as that of the Spaulding Precipitator, and was suggested by one of our Durham chemists, now Captain L. A. Lubow, U. S. Army. For experiment a separatory funnel of 500 mls. capacity was employed with success. Here the relative water velocities, base to vertex, were approximately 75 to 1. Later a two-liter cone-shaped device was made available by one of the laboratory supply houses. We have continued to use the two-liter cone since that time and have tentatively named it the "Contactor."**

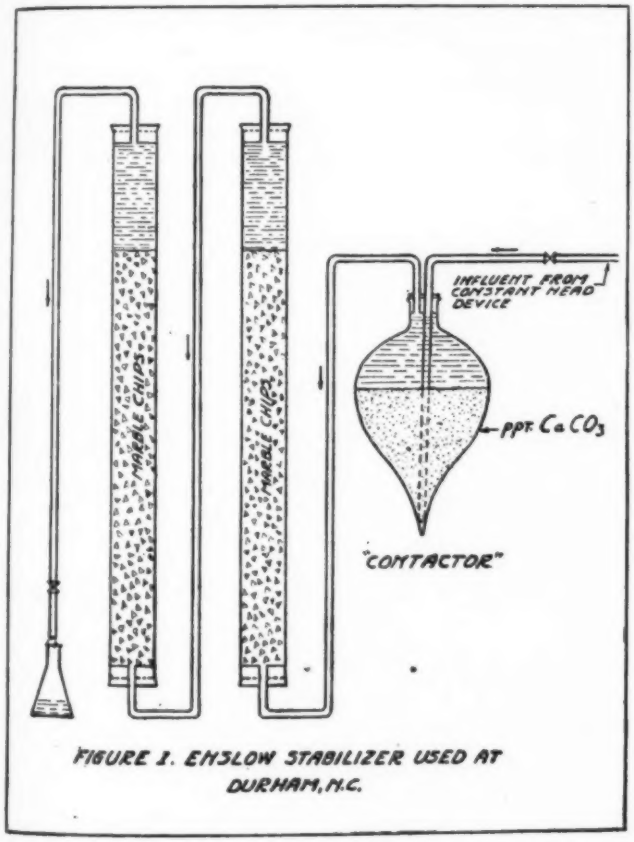


Fig. 1—The Original Enslow Stability Indicator to Which the Durham "Contactor" Has Been Added

The "Contactor" provides intimate contact with fine precipitated chalk; high velocities at the vertex cause a moderate expansion of the entire mass of chalk, allowing the water in its upward travel, under decreasing velocity to "filter-through"; and the effluent from the "contactor" is substantially clarified, leaving only a small amount of fine material to be filtered or plated out by the coarse marble chips later. See Fig. 1.

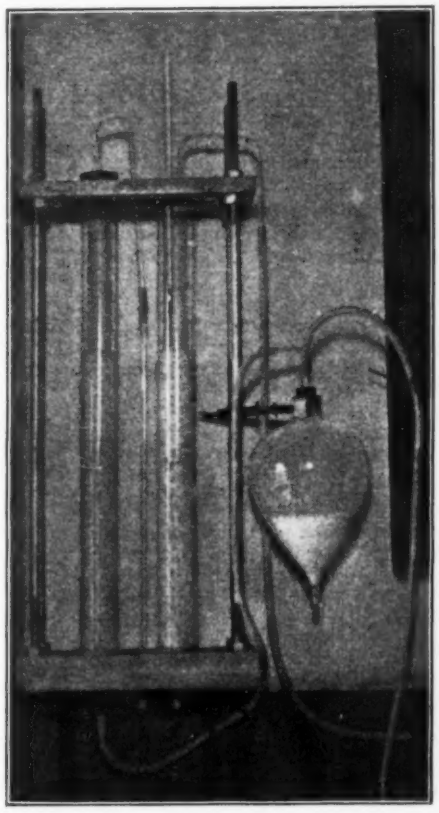


Fig. 2—The Improved Enslow Stability Indicator in Service

Results of Operation

Our Continuous Stability Indicator with the above modification has been in operation since February, 1940. During that period daily samples have been taken at two widely separated points on the distribution system, and compared analytically with samples from the Stabilizer and with the finished water pumped from the treatment plant. One point of sampling is our open elevated storage reservoir, where treated water is retained for an average of one week. The other is at an extreme end of the distribution system, where water use is relatively small. Admittedly these two points represent conditions at which sustained stabilization is most difficult.

Table No. 1 shows the results of a year and a half operation and the average monthly figures in both alkalinity and pH of the water at various points. The figures on total alkalinity indicate that the water was in equilibrium and that it did not tend to dissolve or deposit calcium carbonate. In other words, within the limit of accuracy of tests, the water was well-stabilized when treated according to indications given by the Enslow Stability Indicator.

It will be noted that the pH of the Stabilizer effluent is lower than that of the treated or tap water, although the alkalinity will be the same. This is believed to be due to the fact that small amounts of gases, such as CO_2, are dissolved in Stabilizer effluent while dripping into the container. For this reason, we disregard the pH readings on the Stabilizer effluent and treat, instead, to maintain a final treated water alkalinity equal to that shown by the Stabilizer effluent.

Enslow Index vs. Langlier Index

Since 1937 we have been determining the Saturation Index by the Langlier Formula[2]. For comparative purposes I have included a column labeled "Langlier pHs," which is a monthly average of the Langlier pH of saturation. It indicates that on an average the pH of saturation indicated by the Stabilizer is somewhat lower than that calculated by Langlier formula.

In the early fall of 1940 an interesting change took place which illustrates the practicability of the Continuous Stability

**Phipps and Bird, Inc., Richmond, Virginia, now manufactures an Enslow Stabilizer which includes the Durham "Contactor."

Indicator. We had been taking untreated water from one source which was practically identical in characteristics to that of another source. The only apparent difference was one of carbon-dioxide content and a depressed pH. A change was made from one source to the other. No alteration in coagulant dosages was required, yet the following changes occurred in the Stabilizer Effluent overnight.

	Raw Water No. 1	Raw Water No. 2
Date	9-23-40	9-24-40
Turbidity, ppm.	70	65
Alkalinity, ppm.	15	14
Free CO_2, ppm.	13	6
pH	6.2	6.7
Stabilizer Eff. pH	8.2	8.8
Stabilizer Eff. Alkalinity, ppm.	29	21

It must be admitted that considerable changes of this magnitude could not have been foreseen or predicted by any other simple method.

Some Notes on Operation

The total water capacity of the Stabilizer used at Durham is 3230 mls. exclusive of the volume occupied by the chalk and marble chips. The capacity of each part individually is as follows:

	Mls.
"Contactor"	2050
Twin tubes filled with marble chips (590 mls. ea.)	1180
Total capacity	3230

Each of the twin tubes contains about two and one-half pounds of marble chips. The "Contactor" contains approximately 200 gms. precipitated calcium carbonate. The latter is introduced into the "Contactor" mixed with 500 mls. water. The cone is filled completely with additional water and the mass allowed to settle thoroughly before placing into operation.

The normal operating rate is 25-35 mls. per minute, resulting in a contact period of approximately two hours. The "Contactor" alone provides nearly two-thirds of the total time. It is very important that the rate shall not ever materially exceed the upper limit, otherwise the purpose of the "Contactor" will be defeated by carrying over fine calcium carbonate into the effluent. A slower rate is satisfactory and for some waters the longer contact period may prove an advantage.

TABLE NO. 1

MONTHLY AVERAGES

	pH					Alkalinity as $CaCO_3$, ppm.			
1940	Enalow Stabilizer pHs	Langlier pHs	Tap	Reservoir	End Distribution System	Enalow Stabilizer Eff.	Tap	Reservoir	End Distribution System
March	9.0	9.0	9.1	9.0	8.6	20	21	20	21
April	9.1	8.9	9.1	9.1	9.0	23	24	23	24
May	8.7	9.0	8.8	8.9	8.8	26	24	25	25
June	8.4	8.8	8.6	8.6	8.5	23	23	23	24
July	8.4	8.9	8.6	8.5	8.5	25	23	23	22
August	8.3	8.8	8.5	8.4	8.5	27	27	26	23
September	8.5	8.8	8.7	8.5	8.5	24	25	24	25
October	8.7	9.0	9.0	8.7	8.8	24	25	24	24
November	8.8	8.9	9.0	8.9	8.9	25	25	27	25
December	8.9	9.0	9.1	9.1	a.	20	21	22	a.
1941									
January	9.1	9.0	9.1	9.1	8.9	23	23	23	22
February	9.0	9.0	9.1	9.1	9.1	21	22	22	23
March	9.0	9.0	9.1	9.0	9.1	21	21	22	23
April	9.0	9.0	9.1	9.1	9.0	22	21	22	23
May	8.9	8.9	9.1	9.0	9.0	23	25	24	25
June	8.6	8.9	8.8	8.8	8.7	26	27	26	28
July	8.5	8.8	8.6	8.6	8.6	27	28	27	29
August	8.4	8.7	8.5	8.5	8.5	33	33	33	32
Average	8.74	8.91	8.88	8.83	8.76	24.0	24.3	24.2	24.8

a. No samples taken.

It is advisable to mount the Stabilizer in a place out of direct sunlight to avoid the possibility of microscopic growths.

Occasionally it will be found desirable to clean the entire system and introduce new calcium carbonate into the "Contactor." A dilute solution of Hydrochloric Acid followed immediately by a thorough rinsing with water seems to accomplish the desired result quickly and efficiently.

After placing the Indicator in operation it will be found that some of the extremely fine (almost colloidal) chalk will be swept over for the first day or two. After this the effluent clears entirely, the colloidized chalk, if any, plating out on the marble chips.

References

1. "The Continuous Stability Indicator," Linn H. Enslow, *Water Works and Sewerage*, 86:107 (1939).

2. "The Analytical Control of Anti-Corrosion Water Treatment." W. F. Langlier, *Journal A.W.W.A.* 28:1500 (1936).

WEIGHTS OF MATERIALS

Pounds per Cubic Foot — Average

BRICK	
Common Red	100
Silica	105
CEMENT	
Portland	94
Hydraulic	60
COAL AND COKE	
Anthracite	53 to 57
Bituminous	49
Charcoal	18
Coke	26
CONCRETE	
Cement, fine	137
Rubble, coarse	119
EARTH	
Loam, dry, loose	76
Loam, packed	95
Loam, soft, loose mud	108
Loam, dense mud	125
LIME	
Quick, loose lumps	53
Quick, fine	73
LIME STONE	
Large blocks	168
Irregular lumps	96
MASONRY	
Granite or limestone	165
Mortar, rubble	154
Dry	138
Sandstone, dressed	144
METALS	
Aluminum	166
Brass, cast	524
Bronze	534
Copper, cast	537
Copper, rolled or wire	555
Iron, cast	450
Iron, wrought	482
Lead, cast	708
Lead, rolled	711
Steel, cast	490
Steel, rolled	495
Tin, cast	459
Zinc, cast	438
OILS	
Engine	55
Crude	48
Petroleum	55
Gasoline	43
SAND	
Dry and loose	100
Dry and packed	110
Wet and packed	130
Gravel, packed	118
Gravel, bank	111
Gravel, dry	74
WATER	
Water, as ice	59
Water, at 32° F.	62
Water, at 212° F.	60

SIMPLIFIED BACTERIOLOGICAL PROCEDURE FOR THE EXAMINATION OF WATER

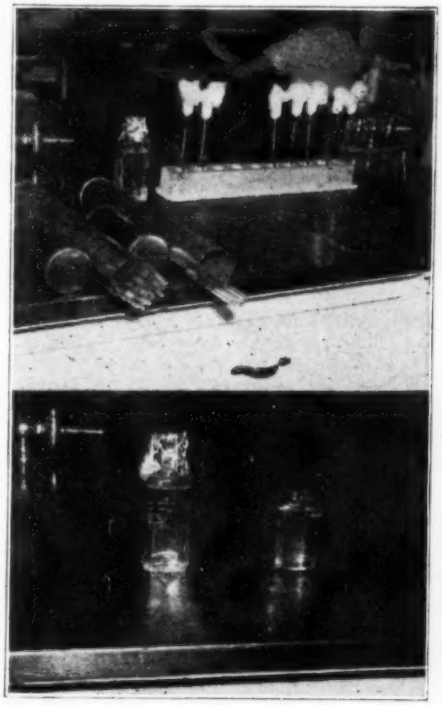
By CHARLES A. HUNTER, Ph.D., ELEANOR PATTY, A.B., and FLORA McKINLEY, M.S.
Public Health Laboratories, Kansas State Board of Health, Topeka, Kansas

THE primary object of the bacteriological examination of water is to determine whether it is safe for domestic use. The procedure should be simple, rapid and efficient—a procedure which all laboratory workers can follow with a minimum of deviations. Changes have been made in each new edition of *Standard Methods of Water Analysis*, attempting to improve and to increase the efficiency in detecting and identifying the coli-form groups of organisms. But with the addition of special tests and details of procedures there also arises the possibility of losing sight of the *real* object of water analysis.

The latest edition of *Standard Methods*[1] recommends that lactose broth be used for the presumptive test—taking gas formation to be an indication of coliforms. It is recognized that the formation of gas may be due, not only to coliforms, but to lactose fermenting spore formers, to synergism, or entrapped air. And, due to the possibility of false positive reactions, it is necessary to run confirmatory tests on *all* tubes showing gas formation, thereby making the so-called presumptive test little more than an enrichment culture. Gas production as an indication of positive presumptive tests is not reliable due to the difficulty for some laboratory workers to determine if gas has formed or not. Some workers consider the presumptive test negative if the amount of gas observed within the inverted tube is less than 10 per cent by volume. Also some workers try to decide whether the gas is actually due to fermentation or is largely entrapped air. All of these personal interpretations are deviations from the standard methods and, therefore, the results may not be reliable.

Many Methods Looking to Improvement Proposed

Many methods have been proposed for the elimination of false presumptive tests by adding various chemical agents (see 2-13 inclusive in appended reference list), but most of them have not proved satisfactory.



A Comparison

Above is equipment required in standard methods procedure for making the presumptive test. Below, the equipment required in the simple bottle method—8 oz. graduated culture bottle and water sample.

The importance of false presumptive tests can be illustrated by considering the results of the bacteriological examination of 764 water samples. Positive presumptive tests were obtained in 595 waters, of which only 460 confirmed, thus 135 samples or 22.7 per cent gave false positive presumptive tests.

It is the opinion of the authors that, so long as mere gas formation is accepted as a basis of the presumptive test, little improvement can be made. There is a real need for a simple, efficient and economical method which will get rid of some of the pitfalls and needless work and time requirements in our present standard methods.

A Simplified Method Suggested

The method to be reported here is a modification of a method first recommended by Weiss and Hunter.[24] This method uses a larger quantity of water and eliminates gas production in the presumptive test, thereby preventing false positives. It is a simple, reliable, economical method. Various experiments with this method have been carried out on several thousand samples of water during the last two years. The outline of the methods used in this series of experiments follows:

Bottle Method

Materials

(1) *Bottles:*

Graduated 6 or 8 oz. inexpensive and easily handled screw cap prescription bottles.

(Most of the bottles, at the present time, have plastic caps and are of various composition. Some caps, upon sterilization, give off ammonia or formaldehyde which may be absorbed by the medium and may affect the growth of the organisms. It is recommended that experiments be run on each lot of caps to determine whether volatile toxic substances are formed on sterilization. The use of glass stoppered, graduated bottles would be better.)

(2) *Medium (Concentrated):*

Tryptose	400.00 grams
K_2HPO_4	40.00 grams
KH_2PO_4	20.00 grams
Water	1000.00 cc.

Filtration and adjustment of pH is not necessary. Final pH is 6.8 to 7.0. Add 5 cc. to each bottle and sterilize at 15 pounds for 15 minutes.

(3) *Confirmatory Medium:*

Brilliant green lactose bile 2 per cent. Use in fermentation tubes.

Techniques

These pictures compare the more tedious time and equipment consuming and expensive procedure of the standard method (left) with the simple and inexpensive bottle method (center) of setting up the water sample in the graduated culture bottle; and (right) transferring a loop of enrichment culture from incubation bottle to confirmatory fermentation tubes.

TABLE I

Comparison of the Standard Method and the Bottle Method Using Both the Completed Test and the Liquid Confirmatory Medium (B.G.L.B.)

Number of Water Samples	Standard Method								Bottle Method							
	Completed Test				Liquid Confirmatory B.G.L.B.				Completed Test				Liquid Confirmatory B.G.L.B.			
	Positive		Negative		Positive		Negative		Positive		Negative		Positive		Negative	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
764	460	60.2	304	39.8	477	62.4	287	37.6	492	64.4	272	35.6	502	65.7	262	34.3

TABLE II

Total number of water samples, 764	A		B	
	Completed Test		Liquid Confirmatory B.G.L.B.	
	Number	%	Number	%
Number showing coliform by both methods.....	444	58.1	458	59.9
Number not showing coliforms by both methods..	255	33.4	243	31.8
Number in disagreement.....	65	8.5	63	8.3
Standard methods + bottle method —	16	2.1	19	2.5
Standard methods — bottle method + ...	49	6.4	44	5.8
Difference in favor of bottle method.....	33	4.3	25	3.4

Procedure

(1) *Enrichment Culture:*

(a) To each bottle containing 5 cc. of the concentrated broth add 100 cc. of the water sample.

(b) Incubate broth at 37° C. for 18 to 24 hours.

(2) *Confirmed Test:*

(a) Shake bottle well and transfer one loop (not less than 3 mm. in diameter) of the broth from the bottle to a brilliant green lactose bile fermentation tube.

(b) Incubate the fermentation tube at 37° C. for 48 hours.

(c) The presence of gas in any amount within 48 hours constitutes a positive confirmed test.

(3) *Completed Test:*

When brilliant green lactose bile broth is used as a liquid confirmatory medium, in routine examinations, it is not necessary to carry out the completed test of *Standard Methods*. In the experiments, the results of which are reported here, the completed tests, as recommended in *Standard Methods*, were carried out for the sake of comparison.

Standard Methods

The procedure in *Standard Methods* was followed, but the brief outline below gives the variation of the method as used in our laboratory.

(1) *Presumptive Test:*

Seven lactose broth fermentation tubes inoculated as follows: one 0.1 cc.; one 1.0 cc., and five 10 cc. portions.

(2) *Confirmed Test:*

All primary lactose fermentation tubes showing gas within 48 hours at 37° C. were transferred to brilliant green lactose bile 2 per cent fermentation tubes.

(3) *Completed Test:*

All brilliant green lactose bile fermentation tubes showing gas were streaked on EMB plates and typical (or atypical) colonies fished off into brilliant green lactose bile fermentation tubes, lactose fermentation tubes, and plain agar slants.

Water Samples

The majority of the samples of water were from raw, untreated supplies collected from all parts of Kansas by county health officers, engineers, nurses and sanitarians, and sent by mail to the laboratory. A few of the samples were from swimming pools and treated water supplies.

Results

The results obtained from the experiments comparing these two methods are given in Tables I and II.

The results in Table I give the total number of positive and negative tests for the coliform group by the two methods, when confirmed by the complete test or by the liquid confirmatory medium (B.G.L.B.). For a little clearer picture of the results Table II is presented.

Considering the results as given in column A (completed test) it can be seen that the bottle method is more efficient in detecting coliforms than the standard method, as evidenced by the fact that the bottle method picked up 49, or 6.4 per cent, more waters showing coliforms than did the standard method. It is also noted that 16, or 2.1 per cent, of the waters were positive by the standard method and negative by the bottle method. However, the difference in favor of the bottle method was 33, or 4.3 per cent.

The results given in column B (liquid confirmation medium, B.G.L.B.) show that there are a few more positives than were obtained by the completed test. It has been observed that the slow lactose fermenters form gas in brilliant green lactose bile within the limits of the incubation period, whereas, no gas is formed in lactose broth. It is believed that brilliant green lactose bile is as satisfactory for confirming the coliforms as is the longer procedure used in the completed test.

Summary

Briefly the advantages of the bottle method are as follows:

1. More efficient and reliable.
2. Rapid.
3. Eliminates gas production in presumptive test.
4. No false positives.
5. Less chance for contamination.
6. Simplicity both in technic and equipment.
7. Economical.

a. Less equipment, test tubes, pipettes, racks, etc.
b. Less media.
c. Decreases time in preparing media.
d. Less dishwashing.
e. More samples run per person (10 by bottle method to 1 by standard method).

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CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

Director of Laboratories, Dept .of Water Supply, New York City.

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into areas by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by a barrel arrangement. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sits on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4 . 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA

Organisms—Odor:	Copper Sulphate[1] Parts per million	Copper Sulphate[1] Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡ Aromatic, geranium, fishy	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Cyclotella†‡ Faintly aromatic			1.0
Diatoma† Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡ Earthy	0.36*-0.50*	3.0-4.2	1.0
Stephanodiscus	0.33	2.8	
Tabellaria‡ Aromatic, geranium, fishy	0.12*-0.50*	1.0-4.2	0.5*-1.0
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡ Grassy, nasturtium, fishy			0.5*-1.0
Draparnaldia	0.33	2.8	
Eudorina Faintly fishy	10.00	83.0	
Entomophora	0.50	4.2	
Glœocystis Offensive			
Hydrodictyon† Very offensive	0.10	0.8	
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina Faintly fishy	10.00	83.0	
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡ Fishy	0.25	2.1	0.3*-1.0
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡ Moldy, grassy, vile	0.12*	1.0	0.5*-1.0
Aphanizomenon‡ Moldy, grassy, vile	0.12-0.50*	1.0-4.2	0.5*-1.0*
Clathrocystis Sweet grassy, vile	0.12*-0.25*	1.0-2.1	0.5*-1.0
Cœlosphærium‡ Sweet grassy	0.20*-0.33	1.7-2.8	0.5*-1.0
Cylindrospermum Grassy	0.12	1.0	
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia Moldy, grassy			
Protozoa:			
Bursaria Irish moss, salt marsh, fishy			
Ceratium†‡ Fishy, vile, (rusty brown color)	0.33	2.8	0.3*-1.0
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas Candied violets	0.50	4.2	
Dinobryon‡ Aromatic, violets, fishy	0.18*	1.5	0.3*-1.0
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium Fishy	0.50*	4.2	
Mallomonas Aromatic, violets, fishy	0.50	4.2	
Peridinium Fishy, like clam-shells	0.50*-2.00	4.2-16.6	
Synura‡ Cucumber, muskmelon, fishy, bitter taste	0.12*-0.25	1.0-2.1	0.3*-1.0
Uroglena‡ Fishy, oily, cod-liver oil taste	0.05*-0.20*	0.4-1.6	0.3*-1.0
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa† Very offensive decayed	5.00	41.5	
Cladothrix	0.20	1.7	
Crenothrix†‡ Very offensive decayed, medicinal with chlorine	0.33 -0.5*	2.8-4.2	0.5*
Leptothrix†			
Sphaerotilis, natans† Very offensive decayed	0.40	3.3	
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis† Objectionable	0.10 -0.18*	0.8-1.5	
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

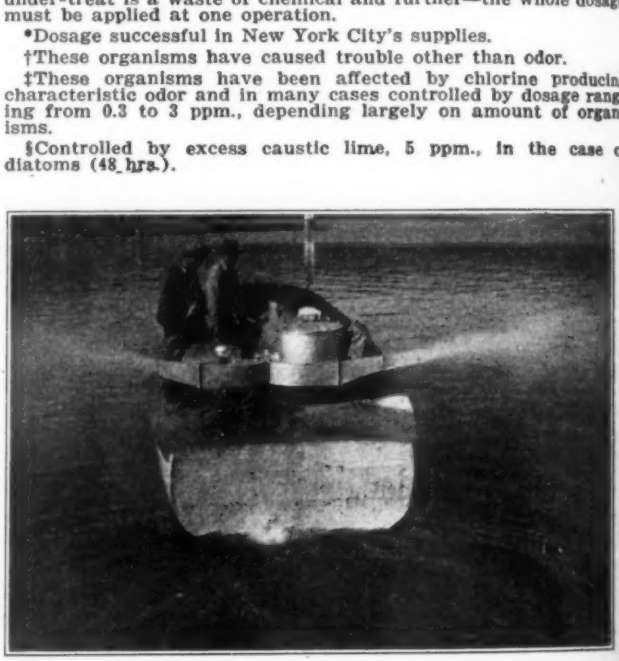
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



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By VESTER OPIE, Chief Engineer
Dept. of Water, Light and Ice, Paris, Mo.

AT Paris, Mo., we wanted to use activated carbon for the removal of tastes and odors from our water which is coagulated and filtered. Faced with the problem of not having a dry chemical feeder we decided to try feeding this chemical in solution form. Of course we soon learned that powdered activated carbon, being insoluble, would require continuous mixing of the water-carbon mixture while feeding it to the raw or settled water. We also found that in feeding through a small orifice trouble occurs from coating up or choking of the orifice by the insoluble carbon or bits of foreign materials.

The Feeder

The accompanying photograph and sketch of the combination solution tank and feeder are self explanatory. The tank consists of a steel drum in which is mounted a small Pemberthy Sump Pump. The tank is filled to the desired depth with water, the pump is started and the desired charge of powdered "Nuchar" carbon is added.

Since the sump pump is running, and the arrangement of the main discharge pipe is such as to cause a rapid swirling agitation in the tank, the carbon quickly goes into suspension. The pump runs continuously, or as long as the feeder is in use at least, and a portion of the emulsion passes up through the small riser pipe to the tee containing the glass or metal tube orifice. While a portion passes through the small feed control orifice, and into the funnel and to the rubber hose feed to the point of application, the greater bulk of the carbon-water mixture passes by the orifice and discharges back into the tank through the riser pipe.

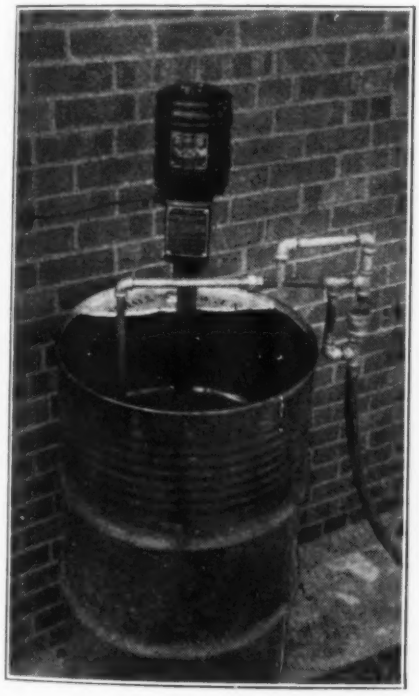
By this simple scheme a constant head is held on the feed orifice. At the same time the high velocity with which the liquid passes by the orifice maintains a clean orifice inlet and also prevents stoppage by any bits of bag paper or other foreign matter which may get into the tank.

Dosage Regulation

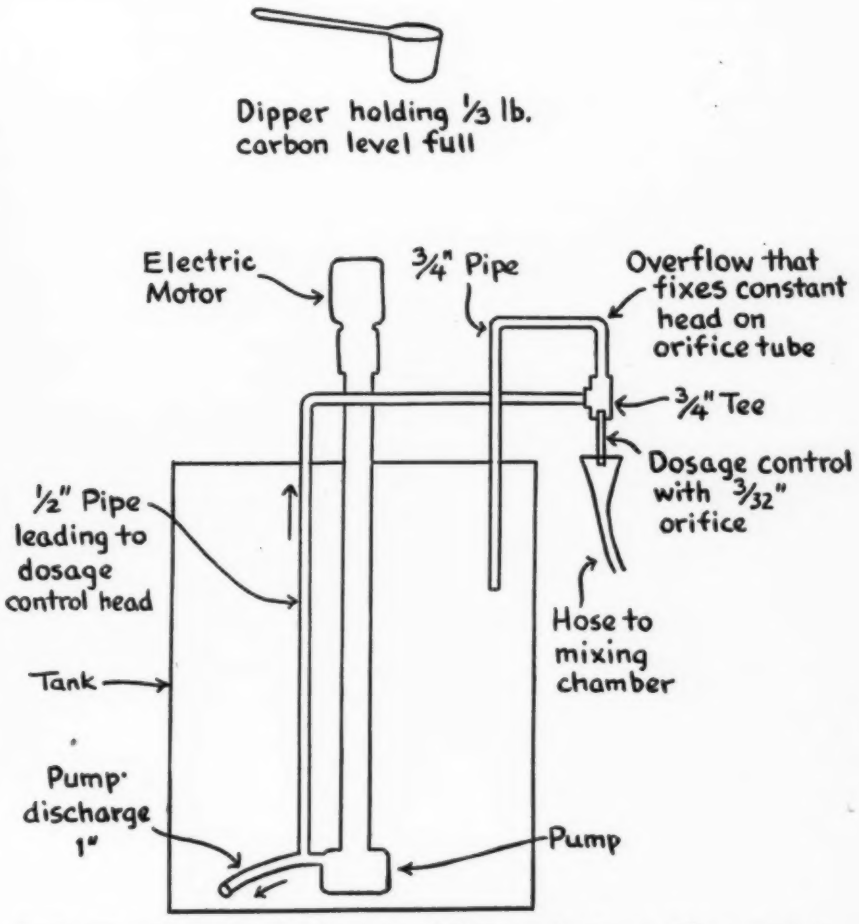
It is evident that dosage of carbon or any other material being fed can be regulated by one or more of three schemes. First, the emulsion can be made heavier (or lighter) in material added in making up the batch in the tank. Second, the orifice can be replaced with one larger or smaller. Third, the head on the orifice can very readily be changed at will by inserting nipples of various lengths in the orifice tee, those extending the height of the vertical return line. Or the same may be accomplished by inserting a plug-cock in the solution return line. By setting the plug at various degrees of opening, the desired head can be secured on the orifice within the range above which there will be no recirculation unless the main discharge pipe at the bottom of the tank be throttled also.

In the unit shown a 3/32-in. orifice tube is used. The tube extends up into the tee on purpose, since in this way the flow sweeps past it at high velocity to keep it clear of possible chokage. For measuring the carbon a dipper, level full, holds exactly a third pound of "Nuchar" carbon. For every 10 gallons of water run into the tank (drum) add one even dipper full of the carbon. The water added is measured through a water meter, which is simpler than taking depth measurements when adding new water to the tank.

This feeder has been in use now for more than three years and has been very satisfactory.



Activated Carbon Feeder
In solving our problem of feeding activated carbon the combination solution tank and orifice feed arrangement (with constant head), which is here illustrated, was built. It has worked with entire satisfaction.



Section Through Feeder, Showing Recirculating—Mixing Pump, Piping and Orifice Arrangement.

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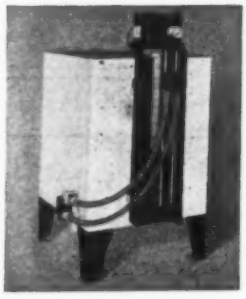
GRAVIMETRIC FEEDER

"Loss-In-Weight" Type

The most accurate type chemical feeder made. Indicates on the scale beam the weight of material in the hopper at all times. Feeds lump, granular or powdered materials at 100 different rates by increments of 1% of the maximum rate of feed, and records every pound of material fed. No calibration is required. The rate of feed is automatically controlled by the loss in weight in the hopper of material. The No. 1 Feeder shown at left feeds up to 2,000 lbs. per hour. Bulletin on request.

PRECISION FEEDER

Not an orifice feeder but a true Volumetric feeder, accurate within 1% for feeding solutions of Calgon, hypochlorite, copper sulphate, ammonium sulphate, etc., by gravity. Feeding range 100 to 1, from 1/25 to 200 gals. per hour, with standard tank sizes 25 to 200 gallons. Where electricity is not available, 8-day spring motors are used; meter-paced control is easily accomplished by flow proportional feeding. Bulletin on request.



UNIVERSAL FEEDER

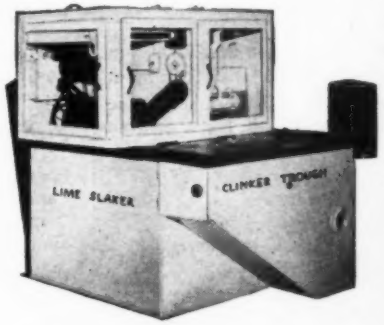
A rugged, dependable Volumetric feeder with oscillating throat at base of hopper. Easy micrometer screw adjustment gives a practical range of 40 to 1. Three sizes provide a feeding rate of 1 to 6,000 lbs. per hour. The feeder will successfully handle lime containing both lumps and fine powder; strings and trash will pass on through without clogging. Accuracy averages 3% although crushed lime may vary somewhat in weight per unit of volume. Send for Bulletin.

OMEGA LIME FEEDERS AND SLAKERS

Omega Continuous Lime Slakers are the product of years of specialization in the design and construction of equipment for Municipal Water and Sewage Plants. The majority of Omega Lime Slaker installations employ either the Belt Type or Loss-In-Weight Type Gravimetric Feeders. Slakers are available with capacities from 175 lbs. per hour to 10,000 lbs. per hour.

Outstanding features of the Omega Lime Slaker include:

- High speed mixing to promote rapid, thorough slaking.
- Efficient insulation and thermostatic heat control to maintain high slaking temperatures.
- Vapor removal devices to protect feeders from hot, moist vapors.
- Heat exchanger coils to preheat cold water for increased slaking efficiency.

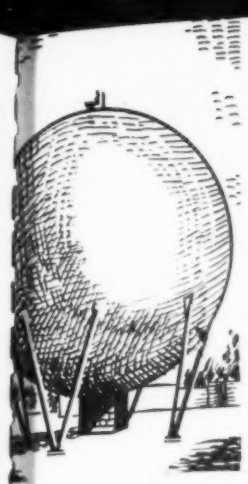


OMEGA BELT TYPE GRAVIMETRIC FEEDER AND 500 LB./HR. OMEGA SLAKER

A feeder of extreme accuracy, weighing material continuously on a short conveyor belt carried on accurate sensitive scales. Can be set by a single dial to feed within 2% of the desired rate, and any departure from weight per unit of volume is automatically compensated. Alarms prevent over or under feeding; totalizer and recorder keep complete records of material fed. Automatic devices for feeding in proportion to variable flow are available. Bulletin on request.

ROTODIP FEEDER

For feeding from large supply tanks which may be located at a distance from the feeder. This cut-away view shows the metering wheel discharging into the receiving box at a high rate. Feeding range 1 to 800 gallons per hour. Variable speed drive gives an infinite number of speed changes from zero to maximum. Liquid feeders and dry feeders may be accurately synchronized to make up fixed strength solutions or suspensions.



PART 7

SEWAGE TREATMENT

WATER & SEWAGE WORKS

REFERENCE & DATA SECTION

1946

J. C. FITZGERALD

P. O. BOX 289 — CORAL GABLES 34, FLORIDA

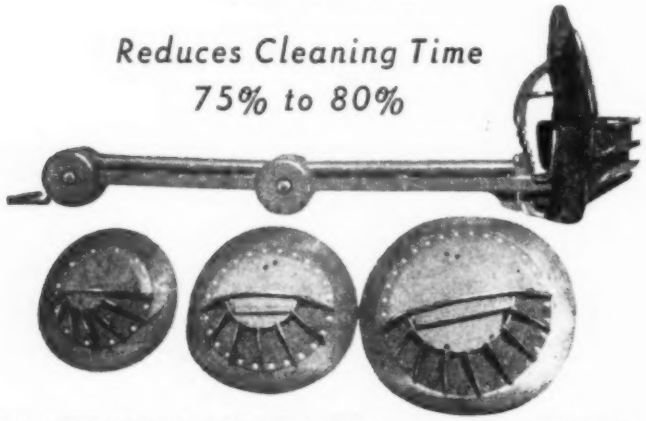
Manufacturer of

The "SEWER SCOOTER" • 100% Self-Propelling Sewer Cleaning Machine

(U.S. Pat. 2198823)

REMOVES
SAND, GRAVEL,
ROCKS, BRICKS,
MUD, GREASE,
BROKEN RODS,
METALS, Etc.

Reduces Cleaning Time
75% to 80%



NO OPERATING EXPENSE. SEWAGE FURNISHES THE OPERATING POWER.

•

NO PRELIMINARY WORK REQUIRED.

COLLAPSIBLE FOR EASY REMOVAL — A Patented Feature.

The "SEWER SCOOTER" is a patented method of cleaning sewers. It is a self-propelling hydraulic device that operates from the force of the sewage in the sewers. It is different from all other types of sewer cleaning tools as it uses the movement of the sewage to do the cleaning job. The operator has a much easier and cleaner job, the work is completed in less time, with thorough results, than when other type of equipment is used.

There is no trick to operate it. The "Sewer Scooter" is lowered into the manhole, with the control rope attached to the rear of the machine, point the machine into the outgoing pipe and it will draw itself into position. A flow must be established, and if the line is dry, or the flow small, more water may be added from any adjacent hydrant to build up a head or reservoir storage in the manhole behind the machine. It can be operated with one or two foot head of water, but in many places six inch head is sufficient. The rubber-edged, collapsible Shield fits snugly into the pipe, forming a dam, and the water builds up behind it. It eases itself along, pushing the debris ahead until its progress slackens, when the water in the line fills up to a head of ten to twenty inches in the manhole, the operator gives a short smooth pull on the control rope which collapses the upper half of the Shield, allowing the water to flush past and wear down the accumulations that have piled up in the line. This operation is repeated until the mud, grease, sand, rocks and other sediment is delivered to the lower manhole for removal, and in this manner the "Sewer Scooter" restores the line to its original designed capacity.

The "Sewer Scooter" is designed to pass fixed obstructions that extend into the top half of the sewer, such as plumbers' taps and crushed pipe. Because it will by-pass obstructions in the bottom and sides of the sewer it will pass through places where drag buckets will not go. It cleans inverted siphons under rivers and subways, if they are constructed with fittings not over 22½ degrees.

When obstructions are encountered that are too heavy and solid to be moved by flushing, the shield will push them by using the momentum of the moving sewage in the line to use the "Sewer Scooter" as a ram to bump against the impediment if necessary. If the object refuses to be moved after repeated efforts to dislodge it fail, it will indicate a collapsed section of the line and the exact location can be found by measuring the length of rope that is used, and time is again saved by the location of the exact place of trouble. When the impassable object is reached the "Sewer Scooter" can be pulled back to the starting manhole and removed.

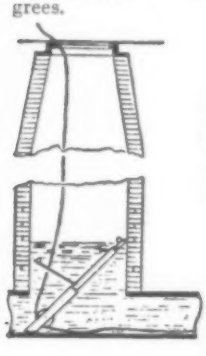
The principal advantage of the "Sewer Scooter" is after the sewers have been cleaned by this method it becomes an easy job to keep them clean by a systematic patrol schedule. The cleaning time required is governed by the amount of refuse to be removed; such sections that load up faster than ordinary will be cleaned when they require it, those that are not in bad condition will be passed through quickly, and the trouble of stoppages will be averted before trouble calls begin to pile up in the office. Cities using the "Sewer Scooter" for over two years report that their trouble calls are less than one-fourth what they were before using this machine.

Another important advantage is, it increases its efficiency with the larger sizes of sewers, so that the larger lines are cleaned in almost the same time that is used to clean the smaller lines, with definitely clean results.

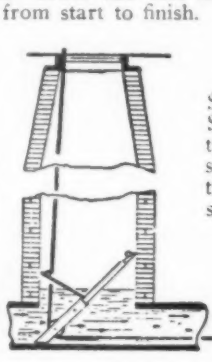
If the "Sewer Scooter" goes through a line just cleaned by some other method, or type of equipment, it will show the amount of dirt, silt and other accumulations that have been left behind. Contractors use this equipment to clean newly laid lines of seepage and sand infiltration that occurs in the construction period.

Write to us for prices, and for names of places in your vicinity that use the "Sewer Scooter."

Showing sand taken from a 21" sewer 320 feet long. The time required was three hours from start to finish.



Showing "Sewer Scooter", with shield closed, in operation in the sewer line. Force of the sewage causes it to move forward, piling up debris as it advances.



Showing shield of "Sewer Scooter" opened by the attached line, allowing the sewage to flush and move the debris along in the sewer.

JOINT ADMINISTRATION AND COLLECTION OF WATER AND SEWER ACCOUNTS

By LEONARD N. THOMPSON, Engineer and General Superintendent

Water Department, St. Paul, Minn.

FROM the outset of the work of the Committee on Joint Administration and Collection of Water and Sewer Accounts, it appeared that there existed a large amount of literature covering comprehensively the subject of sewer rental laws and the many types of sewer rental rate structures. Reference is made at the end of this report to several of these noteworthy publications. To those officials who are interested in the subject and wish to study forms of rate structures, the Committee suggests a review of these papers. The Committee acknowledges the use and study of these publications in the preparation of this report.

While in this report the terms "sewer rental" and "Sewer service charge" may be used interchangeably, the Committee favors the expression "sewer service charge" as more descriptive of the service rendered. This should be considered when preparing material for educational or publicity purposes. Where the sewerage system is already in existence and perhaps paid for, the owner-user sometimes wonders if the "sewer rental" charge means that he is in fact paying twice for the system.

The sewer service or rental charge method has been fairly well worked out, but its application has raised other problems in connection with administration, billing and collection. These problems have, in an increasing number of cases, fallen upon the water department. They have been described very aptly as several series of problems rather than one particular question. On general policy and administration problems little has been written, and in all the data available there has been little to indicate the best practice or to guide the executive.

With full realization that there exists a wide spread in local conditions, that laws, ordinances and local prejudices may be difficult to overcome and that definite standards, applicable under all conditions, are not now possible, it is the hope of the Committee that its conclusions may here produce discussion from which will finally develop definite recommendations to the effectual, economical and workable administrative machinery and practices. These recommendations will then be available as a guide to those now struggling to emerge from their difficulties and to those water works superintendents who suddenly find themselves confronted with the task of collecting both sewer and water charges. Only by full discussion by all those who are interested, and by exchange of information among those having knowledge and experience, can a workable outline be established for others to follow.

Water superintendents have generally hesitated to endorse the joint administration of sewer and water works. Particularly have they been skeptical of the effects on the water department of assuring the collection of sewer service charges. At the start, the difficulties appear many, and it is true that the joint administration, billing and collection of water and sewer bills introduce certain problems, but experience is showing that, with proper rules and methods of procedure, these difficulties are not insurmountable, nor do they appear to place the water department in an unfavorable position.

Sanitation and public water supply are both indispensable services in modern communities; although essentially complementary services, they have developed separately and in the great majority of cities are administered separately. The necessity for enlarged or improved sewage facilities has created new problems in financing, and, concurrently, means for more efficient administration. Not so long ago many cities were struggling under the burden of relief expenses and could not increase their bonded indebtedness. They feared to impose further increases in general property taxes. The revenue bond and service charge method of financing provided a practical solution for the many cities that were able to avail themselves of this method.

Today, with the inescapable necessity of increasing the national debt, state and municipal governments, accounting for approximately one-third of the total indebtedness, will be expected to keep expenses to a minimum. There probably will be some restraint on new issues and in this situation the adaptability of the revenue bond method will prove its worth. Financing out of revenue from service charges—the revenue bond method—which does not add to the bonded indebtedness of the municipality, has gained great favor.

The Committee has attempted to determine the effectiveness of existing legislation permitting the construction of sewerage systems and sewage disposal plants, and of the authority for bond issues, general tax levies and sewer service charges. Twenty-seven states now appear to have adequate satisfactory legislation. Eight report either no legislation at all or unsatisfactory legislation. Two states report that special enabling acts are required, and two report difficulty in the sale of revenue bonds, suggesting need for careful review by the authorities creating the power to issue bonds. In but five of the 42 states reporting did there appear to be restrictions on the creation of metropolitan districts, although a complete analysis of the state laws would have to be made and a legal opinion obtained before a conclusion could be made regarding the actual situation in any state. The fact remains that a great deal of the legislation or amendatory legislation has been passed within the past ten years, indicating the growth in sentiment for water and sanitary districts. Some of this, however, has been emergency legislation and must be given careful study before amendments are offered. While adequate legislation appears to be available in 27 states, in only a few of the states have the provisions been used to any extent.

Replies from 30 water superintendents to a questionnaire on legislation, rules and policies, indicate that the water works profession is far from agreement on its ideas concerning either rates or methods of administration.

The establishment of special boards for the joint administration of the operation of a water department and a sewage disposal plant appears to the Committee to be largely a matter for local decision. Responsibility for maintenance, operation and construction of sewerage systems and disposal works may not, properly, be of concern to the water works administration, often being delegated to other departments. The *actual control* of plant operations of water and sewerage systems under one administrative head, however, would appear to have certain distinct advantages. The *administrative functions,* including the duties of billing and collection, present problems so similar in nature and may effect such economies that control under one administrative head seems most logical and advisable.

Since a water department has already set up the machinery and facilities for both billing and collection, separation of these functions is a duplication of effort and an expense neither justified nor effectually criticized because of the added burden placed on the water works superintendent. Since, generally, those who are beneficiaries of the sewage disposal plant or sewage system of the city are water consumers, the water department already has available the most reliable and complete consumer ledger system.

There is a wide variation in the officials on whom responsibility is placed. A recent survey of 91 cities showed 14 different classifications of officials in charge of sewer systems; 13 of the 91 were water superintendents, 11 joint superintendents of both water and sewer systems. Of 94 cities surveyed, 18 held water departments responsible for sewer rental collections. Thus, it seems that the responsibility for the administration of sewer rental charges is assigned in many ways, depending upon statutory provisions, governmental organization and the basis of rental. With the increased demand for improved sanitary conditions, it is becoming customary to make the water department the responsible agency through which a financial plan and subsequent administration can be worked out.

A superintendent confronted with the problems of joint administration of the two services must, at the start, be concerned with certain definite problems:

1. The matter of legislation or statutory authority: It is highly desirable that such legislation: (1) clearly establish the administrative body and method of financing; (2) grant to such ad-

This paper was presented before the A.W.W.A., at Toronto, Canada, in 1941, by Mr. Thompson as Chairman of the Committee on Joint Administration and Collection of Water and Sewer Accounts and reproduced by permission of the Association.

ministrative body the power to adopt a rate schedule and necessary rules; (3) provide authority for the enforcement of all rules; and (4) make definite provision for the separation and disposition of all funds collected.

2. The determination of the amount of money to be raised by a sewer service charge after a policy has been established regarding the part of such charge that will be used to meet costs of operation, maintenance, betterments, extensions and debt service: When the sewer service charge is based on water consumption the superintendent can make a reasonable estimate of the probable returns. It is desirable that this sum be such that it will be reasonably constant over several years, in order to avoid upsetting charges once they are established. For this purpose it is wise to design rates that will produce a slight surplus which may be used as a cushion against increased costs of sewage treatment or fluctuation in water consumption.

3. The method of raising the desired revenue.

4. The methods of billing and collection and control or accounting.

5. The adoption, by the administrative body, of local rules and ordinances governing the matter of collections, discontinuance of service, discounts or penalties, etc.

With the present high tax rates and, in many instances, tax limitations, every means is being sought to find new sources of revenue. The primary purpose of a sewer rental fund, however, should be to provide for the proper financing of the maintenance and operating costs of the sewage system and sewage treatment works. Practice has shown a wide variation in the extent to which such revenues are relied upon to meet capital, operating and maintenance costs, but the Committee feels that consideration should be given first to the combined method of financing, i.e., assessing the cost of construction against the property benefited and making a service charge for maintenance and operation, with authority to transfer any surplus income from time to time to amortization of the funded debt. Another variation of this method is to include in the service charge the cost of the treatment but not of the sewerage system itself. The revenue bond method for the entire cost is a special consideration and not susceptible to conclusive recommendations.

Installation of a sewer system and disposal plant is beneficial to all properties, even to vacant property, by enhancement of potential values, and therefore, should be taxed for the costs of these improvements. The costs of maintenance and operation are attributable to and equitably chargeable to the users of the works. It is realized by the Committee that tax-exempt property will escape any payment of the capital costs, but legal opinion seems to indicate that sewer rental costs must be uniform and cannot be increased to the user of the system, located on tax-exempt property, when such increases are ostensibly for the purpose of collecting the equivalent of the tax item for construction.

About twenty different forms of sewer rental or sewer service charges are now existent, based upon uniform charges, the quantity of water consumed, the number and type of plumbing fixtures, the number of persons served, the type of premises, the character of the sewage, or upon a combination of one or more of the above methods. The water superintendent, as administrator of such collections, should be vitally interested in and consulted in the establishment of any sewer rental rate structure. While the burden of responsibility for the rates should remain with the sewer division or the city administration, it is highly desirable that they be made with the advice and approval of the water works executive. In establishing the basis, the portion of the total cost which can properly be borne by the city as a whole, i. e., collected by taxation, and the balance to be collected as a reasonable charge against the users, in proportion to the individual benefits derived, must first be determined.

A discussion of the many methods or bases for sewer rentals is covered in the several publications previously referred to, but a study of the many methods and the apparent trend through experience prompts the Committee to favor a charge based on the metered water consumption, either as a percentage of the water bill, or directly on a consumption basis. Directly on a consumption basis, the billing may be at a uniform rate or a step rate. A flat rate is not fair to the small consumer. A rate based on fixtures is difficult to administer. The metered-water method is the closest approximation to the use of system that is practical of application. It is dependent upon complete metering, and modifications have to be taken into account for private supplies and such industries as use large quantities of water which are not discharged into the sewer system. When the water supply is not metered, a flat rate based on the size of the water service or connection, or a charge established as a percentage of the water bill, would produce an approximation of the foregoing method.

The cities of St. Paul, Minneapolis and Detroit have sewer rentals which are typical of the three methods based, directly or indirectly, on water consumption. All three methods have been operating very successfully.

Minneapolis bills for water at the uniform rate of 7½ cents per 100 cu. ft. Sewer rental charges, which are also based on the metered water consumption, are on a sliding rate scale, as follows:

First	100,000 cu. ft. @ 2.8c	per 100 cu. ft.
Next	200,000 cu. ft. @ 1.5c	per 100 cu. ft.
All over	300,000 cu. ft. @ 0.75c	per 100 cu. ft.

The minimum bill rendered is 37 cents.

For one and two-family homes the winter quarter water consumption is used as the basis for sewer rental charges throughout the year. The owner or occupant of this type of property is thus relieved of paying a sewer rental charge on water consumed for lawn sprinkling. Large consumers, of course, receive the benefit of the sliding scale. The annual revenue from sewer rentals is designed to care for operation and maintenance, 60 per cent of the fixed charges of the treatment plant and 30 per cent of the fixed charges on intercepting sewers. The balance of the costs are raised by a mill tax.

St. Paul uses a step rate for water consumption plus a fixed or service charge based on the size of the water meter. The sewer rental charges are only indirectly based on water consumption, being based upon the size of the water meter rather than on consumption directly, as follows:

Size of Meter	Annual Water Service or Demand Charge	Annual Sewer Rental Charges
⅝ in.	$ 3.00	$ 2.40
¾ in.	4.20	3.00
1 in.	7.20	5.00
1¼ in.	10.20	9.00
1½ in.	13.20	15.00
2 in.	27.00	30.00
3 in.	60.00	75.00
4 in.	120.00	180.00
6 in.	240.00	360.00
8 in.	420.00	630.00
10 in.	600.00	900.00
12 in.	.....	1,350.00

The total collections for sewer rentals are used only for costs of maintenance and operation. This city reports that the method has worked well except that, since both the service charge for water and the sewer rental charges are based on the meter size, the department has received several hundred requests for a reduction in the size of the water meters. Reductions granted have, of course, reduced both water revenues and sewer rentals.

Detroit has a three-step water rate plus a service charge based on the size of the meter. The sewer rental rate of 11 cents per 1,000 cu. ft. of water consumed is added to each step of the water rates, and water consumed is billed at the one combined rate to include both water and sewage disposal, as follows:

Water Consumption Charge	Sewage Disposal Rate Per 1,000 Cu. Ft.	Total Rate Per 1,000 Cu. Ft.
First 10,000 cu. ft. per month 78c per 1,000 cu. ft.	11c	89c
Next 900,000 cu. ft. per month 60c per 1,000 cu. ft.	11c	71c
All over 100,000 cu. ft. per month 48c per 1,000 cu. ft.	11c	59c

The service charge is added to consumption charge and all shown as one item on the bill.

In certain localities the presence of one or more industries may so affect the strength or character of the sewage, due to the degree of pollution, that some account must be taken of it in the rate structure. This is particularly true when the cost of operating a sewage disposal plant is involved. Also, in certain industries, where a large amount of water is consumed, provision may be made to discharge the industrial waste so that little if any use is made of the sewage disposal system, or even the sanitary or storm systems themselves. While some cities take no account of this factor, it seems fair to reason that, when a large percentage of the water used is not returned to the sewers, some adjustment in the sewer service charge is proper and even necessary to meet statutory requirements. While the enabling act should provide the authority for such a change, it is the opinion of the Committee that the basic charges, based on water consumption, should still be continued, and such conditions treated as special cases, making equitable adjustments in the charges, and so preserving the simplicity of the general rate structure. The enabling act should give the administration or those invested with power to establish the

rates, proper latitude to make certain uniform adjustments or exceptions to the rate structure.

Many cities are confronted with the problem of private sources of water supply, the water from which finds its way into the public sewer system. Authority for the billing of such accounts for the sewer service charge must be provided. There seems to be no reason why the same rates cannot be applied here as to users of the public water supply.

In St. Paul and Minneapolis there are 376 private wells, producing approximately 40 m.g.d. The two cities report favorably on the complete metering of the private supplies accomplished by ordinance, the sewer rental billing made in Minneapolis being on the water pumped from the private wells, and in St. Paul on the size of the meter as set on the well.

In these cities, where the private supplies have been metered for about eighteen months, it is reported that there has been no particular criticism. In both cities each case was individually investigated and the owner advised regarding type and size of meter. Perhaps the greatest difficulty experienced was the stoppage of meters due to sand pumped from the wells. In St. Paul, where the charges are based on the size of the well meter, the billing is continued until a well is reported out of service and sealed. The installations of small wells for air-conditioning, which are not used during the winter months, are billed throughout the year.

Ordinances should provide for the registration with the billing agency of all old and new sources of private water supplies. These meters should be read and treated as any other account. Since the department has no method of discontinuing such private supplies for non-payment, provision should be made to place delinquencies on the tax rolls or to file them as a lien upon the property.

The trend toward suburban development in many cities has become a real problem. Those who move outside the corporate limits of the city for various reasons, in some cases to avoid city taxation, demand the same utility services they enjoyed in the city. When tax funds have been used to construct and maintain a sewerage system and/or a sewage disposal plant it seems unfair that such facilities should be placed at the disposal of non-residents at less than actual costs. When metropolitan districts are established to furnish utility service to such areas, it is highly desirable that sewer rental charges be increased to represent at least the equivalent amount paid by those taxpayers who are or have paid for the construction of the utilities services. The Committee feels that there is every justification for the creation of metropolitan utility districts, but where those consumers of the service are beyond the tax jurisdiction of the municipality, the payment for such service should represent at least the equivalent of the sum total payments made directly or indirectly by the consumer for like service inside the city, including all costs of amortization, interest, depreciation, maintenance and service.

The difficulties encountered in the collection of sewer service charges are not very great once a sound and workable method is adopted. Sewer bills or sewer service charges may be made separately and entirely independently of the water bill, separately and attached to the water bill, included in the amount of the water bill, or shown as a separate item on the water bill.

There is a natural antipathy among water works men toward confusing the water bill with charges which are primarily of no concern to the water department. Placing additional charges on a water bill, it is felt, will conjure up in the mind of the consumer the idea of an increased water bill. For this reason the practice of making separate bills has often been employed. The committee is of the opinion that the additional expense involved in issuing separate bills is not justified, that experience is proving that a water bill, carefully prepared and explanatory, will neither confuse the consumer nor bring undue criticism upon the water department. It is reported that during the initial stages many inquiries are received but that once the additional charge is understood, the complaints are few.

Simplicity in rate structure and in billing is highly desirable. One of the strongest arguments in favor of a rate based on water consumption is the ease with which the charge may be included with or on the water bill. The bill should be clear and should properly indicate each charge. A statement of the rate schedule is highly advisable. Proper publicity prior to the initiation of the combined method of billing and proper explanation have been found to work successfully and to overcome the fears of the superintendent. Reports indicate little, if any, increased delinquency in the payment of water bills. A printed notice on all water bills to the effect that the water department is acting only as the collection agency for sewer rental charges and that the funds are maintained separately had proved helpful in a number of cases.

Practically all public utility types of billing machines can be so constructed as to indicate the water charge and the sewer rental charges separately, and to tabulate or accumulate the two accounts separately for proper accounting purposes. This process is available even to the extent of duplicating or repeat-printing the amounts of the bill proper and on the cashier's stub. Much clerical and consumer's time may be saved and a clear record kept if all collections made are credited on the one ledger card under proper headings. Accounting control and trial balances are simplified. Separate accounting of each fund is highly desirable, and since the water department is acting only as the collection agency, the funds collected for sewer rental purposes should be credited directly to such an account and turned over to the proper authorities for disposition and disbursement. Colored ledger cards for carrying the accounts of private supplies are desirable and helpful in distinguishing the type of supply easily and quickly, without interference with the financial control system.

Some provision must be formulated in the case of delinquents. Simplicity indicates that the same discount rate or penalty should be applied to sewer and water accounts.

The water department should have the right to instigate all rules governing the method of collection, time or period of billing, to correspond with the regular water billing periods, the rules for collection of delinquent accounts, turn-off for non payment, etc. Since it is not practicable to shut off a sewer connection, the most logical and practicable method of forcing payment of sewer rental charges is to demand that they be paid with the water bill, with right to deny service of both. While on the face of it, it does not seem fair to a water department to be required to deny service to a water consumer because he refuses to pay a sewer rental charge, here again experience shows that the percentage of delinquencies is very small, varying usually from zero to 10 per cent in 37 cities, with one city reporting 20 per cent and two as high as 30 per cent in the depression period. There is no reason to believe that the sewer rental charge on a water bill has increased delinquency.

In practice it will be found that numerous accounts are not connected to the sewer system and, therefore, are not subject to the sewer service charges. In one city a charge is made where the sewer is available, irrespective of whether actual connection is made or not. In another, no charge is made until actual connection is made. In initiating the sewer rental charges in the latter city, the charge, initially, placed on all ledger accounts and billed until complaints and investigation proved the error.

When charges are based on the water consumed and allowance made for lawn sprinkling, it is the usual practice to establish, by a review of the reading sheets, the normal or average consumption for one billing period at each premise as indicated in the off-sprinkling or winter months and to indicate the amount so arrived at on the reading sheets and ledger cards as the average domestic consumption. The sewer service charge is then applied to this same consumption at each billing period. Established percentages of the water charge or fixed charges, when these methods are used, and any other information necessary to billing should be entered on both reading sheets and ledgers. The water superintendent should see to it that his department is reimbursed for all expenses incurred in carrying this added service. These costs may include additional billing equipment, the cost of changing over some equipment to meet new demands, the cost of new ledgers, a fair and proportional share of the postage, clerical and miscellaneous expenses.

The water superintendent should have the complete cooperation of the public works department, sewer department or whatever agency controls the installation of new sewer connections, in order that records may be completely and accurately up to date. Insofar as possible each department should be self-sustaining, free from any political interference and in full control of the revenue received, subject only to the limitation that they be expended for water works and sewerage services and for no other purpose.

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4. Childs, J. A., and Schroepfer, G. J. A review of Sewer Rental Laws and Charges. Sew. Works Jour. Vol. IV, No. 6, Nov. 1932.

5. Allton, Robert A. The Sewer Rental Method of Sewerage Financing. Jour. A.W.W.A., 30: 1285 (1938).

6. *Financing Sewerage Works.* Portland Cement Assn., Chicago.

7. Joint Administration of Water and Sewer Accounts. *Committee Report.* Jour. A.W.W.A., 31: 1957 (1939).

SEWER MAINTENANCE

By C. GEORGE ANDERSEN
Superintendent, Department of Sewers and Sewage Disposal
Rockville Centre, Long Island

In the sewerage problems of today the treatment plant and types and design of sewers seem to take the lead. Now, when one considers the investment in sewer lines as the primary structure, providing an indispensable service in the removal and disposal of sewage, we are in general too negligent in the matter of maintenance and operation of sewers for the best interests of the public and efficient functioning of the treatment plant.

At Rockville Centre the writer, like many other men in charge of sewerage systems and sewage treatment, had his problems. The first was the effective and economical treatment of liquid and solids at the treatment works. Then, after catching up on this important phase of the cycle, in looking around it seemed important to face squarely the other sewerage investment amounting to four times as much,—namely, the sewers. In Rockville Centre we have not so many miles of sewers, nor very large ones, but those we have are as important to proper functioning of the entire system as though they were in a metropolis. The sizes range from 8 to 30 inches, and these sewers clog with roots, sand and many other materials.

Sewer Cleaning

Sewer cleaning being one of our problems, after our sewer lines are laid it becomes a necessity to maintain them in good working condition, and we might just as well lay out a program of routine cleaning and maintenance, rather than wait until trouble overtakes us. Continuing and repeated emergency calls, growing out of sewer stoppages, is very costly. In addition to extra expense there results many disgruntled taxpayers, inconvenienced by stoppages and put to added expense, due to their sewer lateral being plugged because of some backage in the main in the street.

Some Notes on Equipment and Its Effectiveness

For sewer cleaning and removal of roots, there are many types of equipment now available. Flexible steel sewer rods are a recent innovation in such equipment. These rods have an advantage in that the necessity for going down in manholes is eliminated. The rods are made up in three foot lengths, which coupled together make one complete flexible rod that is usually coiled between uses. Wood rods of five foot lengths (coupled together as they are being pushed into the sewer line) also continue in use to some extent. The wood rods, being more rigid than the steel rods, follow a straight line more successfully, but cannot be turned and forced to the extent that the new flexible steel rods can.

The "Turbine" type of sewer cleaning instrument is probably the most positive of all types made today. This device (adjustable to any diameter sewer) is a water powered rotating cutter. In employing the "Turbine", it is necessary to have two winches and cable to draw it through and back between manholes in the line, while the high speed rotating knife blades do a clean job of root cutting and scaping.

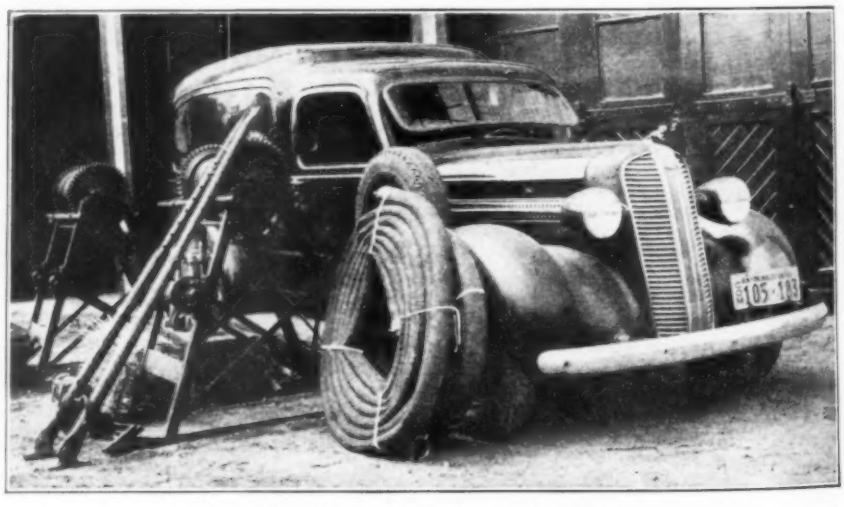
Rods of any kind, which can be used efficiently in making time and mileage when going over an entire sewer system as laid out in a program, are good up to a certain point such as the removal of small deposits and light root growths. On the tougher jobs, such as spots where knob roots have formed (see cut), a more positive applied type of equipment is required. In such cases it becomes necessary to use the "Turbine" cutter, or some similar tool, that will slowly but surely remove the obstruction if it is such as can be cut by steel.

I stress this point, because on one occasion a severe stoppage occurred in an eight inch line. Our Flexible sewer rods were first used, but could only give relief to the extent of four inches. That is, the four inch auger-head was the largest tool that could be forced through. The supposition in this case was that the trouble was caused by a broken spur, being replaced by a makeshift stack which extended into the sewer line. Many other suppositions also were expressed, but there is only one thing to do in a case like this (and such is good for experience)—dig it up. This was done and the trouble was, in fact, at a spur. The spur was not at fault, however, but through the joint preceding it a large root had entered. The question was, how to remove it. A hole was cut in the eight inch tile sewer line so that action of the available cutting tools could be observed as it was applied to the root. The root had formed a five finger knob on the top inside of the pipe (see cut). When the Flexible sewer rod with the auger used in eight inch line was applied to the root the tool just jumped back and had no effect. This satisfied me as to the necessity of having a positive applied sewer cleaning cutter, especially for clearing out those very deceiving *top* roots which cannot be removed by auger and do not stop sewage flow until they are definitely a menace in the sewer.

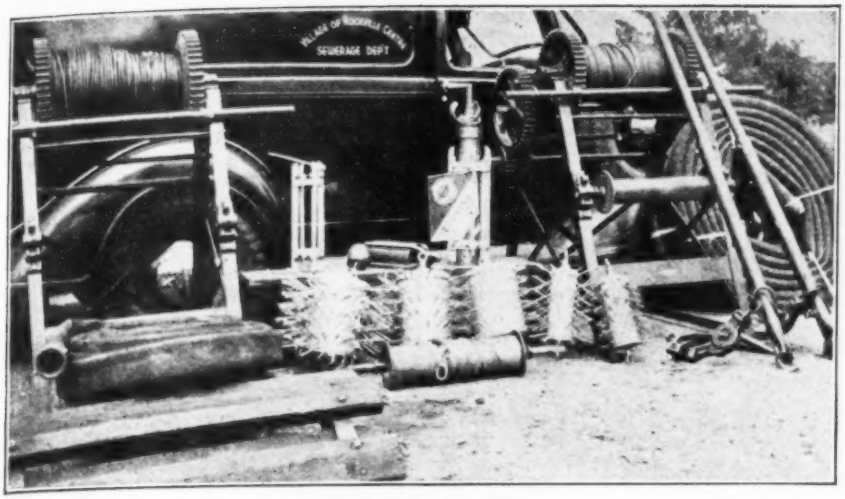
Sand and gravel which have built up around paper, roots and other matter in a sewer, are also a headache. We find that one cannot have *too much* equipment. And, we have also learned that in sewer maintenance different makes of equipment can be used in combination or in sequence to produce very efficient work. Take the case of sand; Flexible steel rods can be used to get an opening through the sand. This constitutes the first important step. Then a cable may be drawn through so as to draw a bullet or tool for loosening and liquifying sand stoppage. Thereafter, the Turbine flusher or cleaning buckets, whichever proves the more efficient, may be used.

Mapping and Program Setting

In setting up our maintenance program, the village map was taken and divided into sections, each section being given a number. In connection with the map, a section book, card index and a daily log book was also established. The section-book is made up of all the sewer sections, showing the sewer lines flush manholes, distances between manholes, etc. Each page (map) covers a separate section (see cut) and the crew operating makes constant use of detail maps in the field. The card index is set up



Our Maintenance Truck and Equipment
A 1½-ton unit, which seems a little light. A 2½-ton unit we believe preferable.



Some of the Equipment

Hose and guards in left foreground; a pair of cable winches, against one which leans cable braces with pulleys inserted in manholes to guide cables. In center, a spool of light threading cable and a set of effective metal scouring brushes (8 to 18 in) supplied by the Turbine Company of Milwaukee. Rear center, on chest containing cutting tools and sleds (6 to 20 in.) for Turbine Cutting heads, is a drag and Turbine Cutter complete for 8 inch jobs.

for each section and any conditions found worth remembering for the future is recorded on such cards. The log book maintained to show a complete record of all work done in connection with maintenance and cleaning, carries daily reports showing the number and location of the work section, the type of equipment found needed, number of feet of sewer cleaned, remarks on conditions, number of laborers employed and cost of the job for the day. A specimen page from the current log-book is here reproduced to better picture the type of entries made.

The plan of maintenance is so arranged that at least 78 miles of sewer will be checked once every three years or 26 miles yearly. The actual working time is 5 days per week during the spring and summer months only, involving in all about 150 days per year of maintenance work. The program is planned and timed to run from March 15 to July 1st, the work being resumed in September and terminated on November 15th. The reason for such a schedule is that it eliminates this type of work in the hot weather and also in the cold winter season, the two most disagreeable times to do this work in an efficient manner at least cost.

In the program the business area is done during the month of June, work commencing at 4 A. M. and stopping at noon. At this time of the day there is the minimum of traffic of any kind to hinder the work, therefore all work that is interfered with by traffic can be completed by the time traffic does start to move The three man operating crew consists of a leader, who must be a reliable, industrious individual, and two day laborers. A sewer inspector (or the superintendent) orders sections of work to be done, and likewise supervises the work and sees that adequate records are kept.

In connection with organization, consideration must be given to equipment mentioned and a transport for such. The truck does not have to be an unsightly thing. We use a 1½-ton black panel job, but find that a 2½-ton unit is preferable, as more space is available for the equipment, which consists of 1000 feet of hose, manhole and hose guards, Flexible rods and cutting tools, water powered Turbine, cutter, shovels, picks, lantern, flags, tools and emergency first aid.

The operation of the maintenance crew is to put through the sewers a tool that will either indicate a clean sewer, or remove stoppage, or determine the necessity for a more detailed job such as "turbining." In their travels they repair masonry in manholes, pack loose manhole lids that disturb residents because of banging under traffic.

In stopping rattling manhole lids many things were used which were unsightly on the streets. A gum was then used and served the purpose for a time. The most satisfactory thing to date has been a tape packing called "Tapax." It is laid around the full circumference of the manhole lid seat, after thoroughly scraping and brushing it clean.

In the larger sewers (15 inch and above) we find that the large wire brushes, that are part of our "Turbine" line of equipment, can be used more efficiently for cleaning and indicating trouble than can the Flexible steel sewer rods.

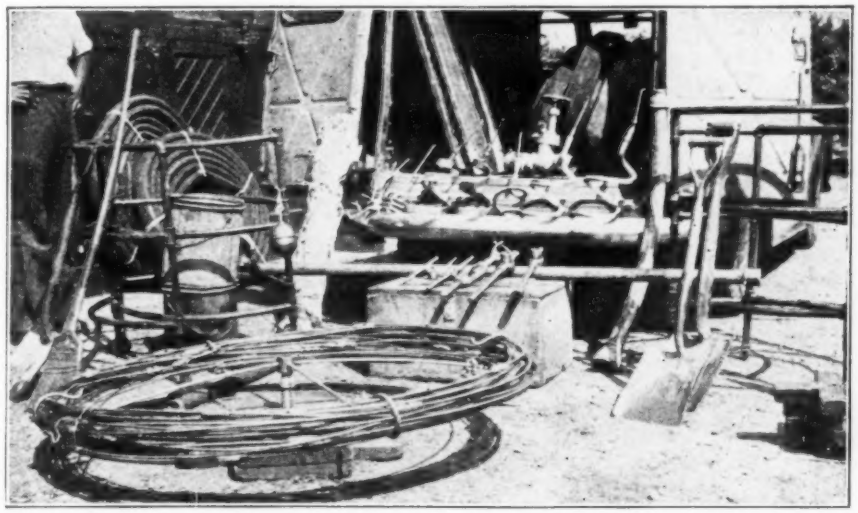
The mere looking down at the flowing sewage, after flushing, does not indicate a clean free-flowing sewer. This much the experience related previously herein has taught us.

Flushing

The basic requirements for effective flushing of sewers are splendidly presnted by J. D. Watson in WATER WORKS AND SEWERAGE for August, 1937. [The same article being reprinted in the Reference and Data Section for 1939.—ED.]

Sewers today are flushed both manually and automatically. The former method is done by using a hose or drawing from pond into the end manhole of a section of sewer line, known as a flush manhole. Also there is the automatic flush equipment frequently installed at the end of a line. The equipment includes a siphon arrangement built into the manhole and discharging into the sewer. The flush tank is continuously refilled by a constant regulated flow of water into it, the rate being controlled by a special faucet. In operation, the flush tank is filled to a certain depth by the water from the faucet. When the head of water is sufficient to cause the siphon to start operation, the siphon empties the tank rapidly and thus flushes the sewer. The idea in all cases of flushing, be it drawn from a pond, by hose, or automatic flush tank, is to cause the flowing off of sewage solids depositing in a flat grade or "lazy" sewer. The hose flushing is the most practical and effective method, as it can be applied anywhere along the line.

The automatic flush, which is still being used, has to be main-



Rear of Truck—More Equipment

Flexible sewer rods connected and coiled on revolving wheel stand. Rear of truck, replacement rods and various types and sizes of augers and screw heads (4 to 10 in.) for Flexible rod work; stop valve for controlling pressure from hydrants used in flushing and Turbine operations; Flexible rod man-hole guides, wrenches and ratchets; man-hole guards flag-stands, etc.

tained. The strainer and orifice through which the water flows to the tank has to be kept clear. Varying pressures in the water main has a tendency to loosen iron deposits which choke the strainer or orifice; also water that has been treated with lime and chlorine causes clogging and trouble with such equipment. There is also the cross connection hazard with this type of equipment which is now being eliminated as much as possible.

As mentioned before, a flow of water will not indicate a clean sewer. Unless properly applied water flow alone will not clean a sewer from a practical man's point of view, other than to flush through material that has been scraped and cut loose or those deposits that are rather easily moved. To clean a sewer effectively involves the removal of films that are building up to a thickness. To accomplish this, the positive scouring type of jetting nozzles must be run through the entire sewer. The flow from a fire plug may seem terrific on entering the line, but very soon levels out to nothing more than a fast flowing stream. As to how much it removes from the walls of the pipes is speculative.

Roots and Service Connections

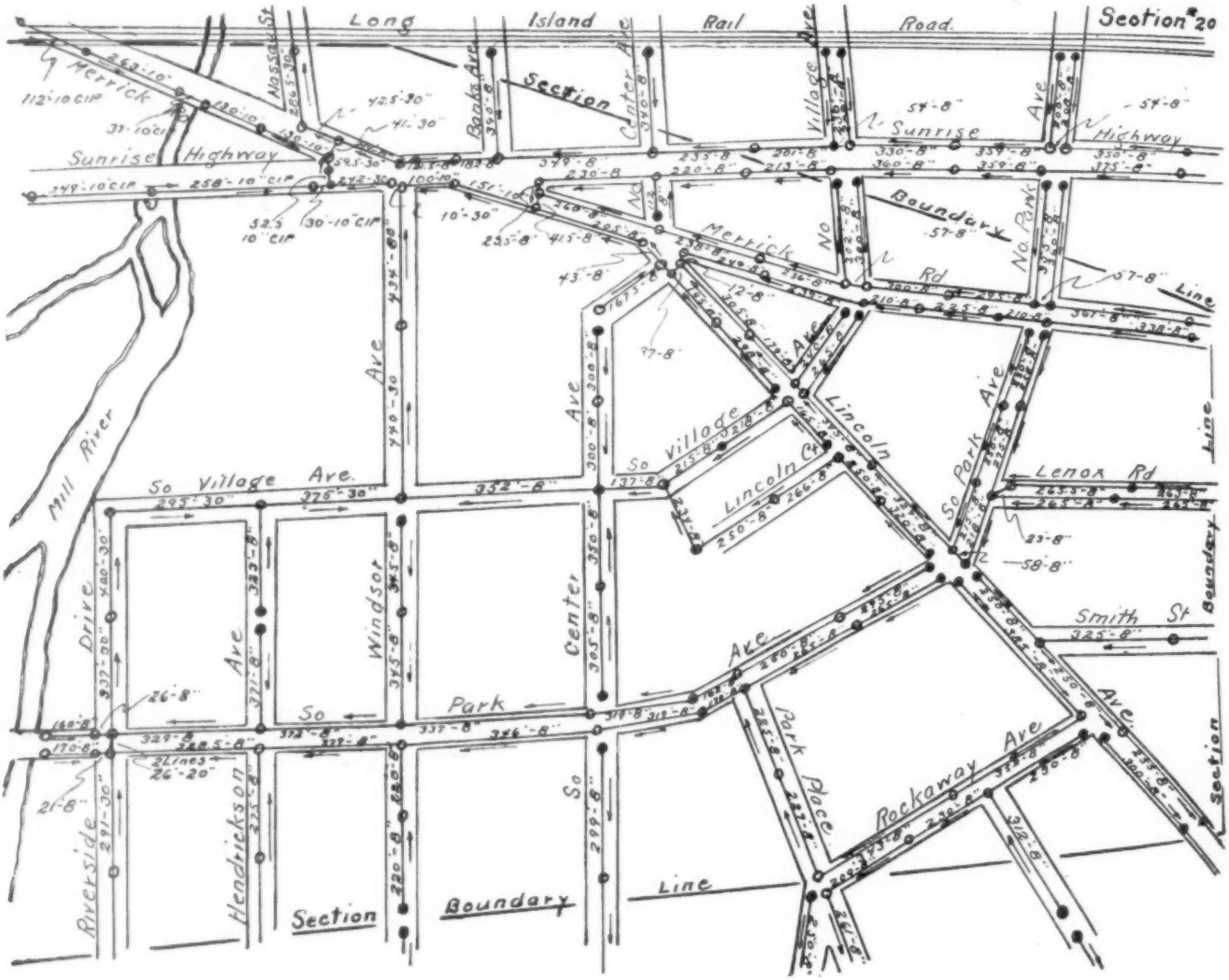
Roots are the big problem in sewer maintenance. We know where they come from—but how to control them? We can to some extent cut down the trouble in the following:

1. Stricter inspection of new lines being laid.
2. Material used for joints. This is no better than workmanship of labor performing the job.
3. Ordinance directed to elimination of the most prolific root growing trees such as poplars, swamp maples, weeping willows, etc.

It has been interesting to hear some of the reports as to how roots will be attracted to sewage, passing up water directly under them and reaching out for a crevice or bad joint in a sewer line. There are many contributing factors—the temperature of sewage, and its content of plant food being the more important.

Service connections into sewers should be inspected as to grade and workmanship of a joint. A poor grade and joint means future trouble for all concerned,—user and Sewer Department. It is so easy to take drain-layer's and plumbers' word for the work done, but once inspected and passed the installation becomes the responsibility of the department passing it. You may argue the point later and think that you have won out, but the taxpayer finally has his day, as we have witnessed so much of late.

The responsibility for maintenance of sewer connections results in a dispute many times. I contend and carry out the policy that where service charges are not made, a sewer lateral should be the sole headache of the one using it. The sewage and waste that is run out to the sewer comes from that property. Any trees in the vicinity are for his comfort, and for a department to take over responsibility from the curb to the main leaves us with the question, Where is the end? Most Sewer Departments have a limited personnel, and to be called out on each house stoppage occurring certainly makes a condition of despair many a time, because of the inability to catch up or demand more labor, which cannot



Detail Map—Section No. 20—Business District

Taken from our Section Map Book covering the 24 sections of the Rockville Center System—Practically indispensable in effective and economical maintenance work, recording, trouble finding, etc.

MAINTENANCE RECORD

MAINTENANCE RECORD

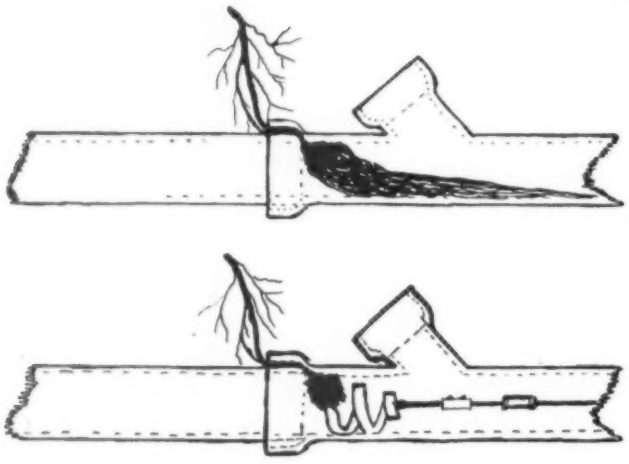
RECORD OF ALL WORK DONE PERTAINING TO MAINTENANCE OF SEWERS

DATE	LOCATION OF WORK	SECTION	TYPE OF WORK DONE: FLEX. RODS	TURBINE CUTTER	FLUSHED	TOTAL FEET CLEANED	MISCELLANEOUS	REMARKS	NO. OF MEN	NO. OF HRS.	COST
4/4/39	So.Park Ave. bet.Lincoln Ave and Center Ave. S/S	20	X		X	489'		Found bad root condition	3	8	
4/5/39	S/S Lakeview west of Greenway St.	1	X		X	180'	On Complaint	Found break in line about 3' from 1st.			
4/11/39	S/S Park Ave bet.Center Ave and Riverside Drive	20	X		X	1053'		d.s.m.h.that filtered water & sand into sewer. Bad root condition.	3	8	
4/11/39	N/S Park Ave.bet.Riverside Dr. and Center Ave.	20	X		X	1038'		Root condition - not bad	3	8	
4/12/39	N/S Park Ave.bet.Center Ave. and Lincoln Ave.	20	X		X	731'		Bad root condition	3	8	
4/12/39	E/S So.Village Ave.bet.Lincoln and Merrick Road	20	X		X	265'	On Complaint	Found roots in this line,no trees			
4/13/39	N/S Park Ave.bet Center Ave. and Lincoln	20	X		X	275'		within 150' of stoppage Bad root condition	3 3	8 8	
4/14/39	Center Ave.bet.Park Ave and Shellbank	20	X		X	869'		Bad root condition - broke several			
4/14/39	Windsor Ave.bet.Park Ave & flush manhole So. of Park	20	X		X	440'		roda Some roots - not bad enough to give	3	8	
4/17/39	Windsor Ave. So. from flush manhole to Shellbank Place	19	X		X	440'		trouble Light roots	3 3	8 8	
4/17/39	S/S Lakeview Ave West about 350' from Hempstead Ave	9	X		X	320'	Demonstration	New Sewer Cleaning tools used	3	8	
4/18/39	Hendrickson Ave. from Park Ave so. to Shellbank Place	20	X		X	980'		Bad root condition	3	8	
4/18/39	Hendrickson Ave from F.M.H. No. to So.Village Ave	20	X		X	323'		Very bad root condition	3	8	
4/19/39	Hendrickson Ave from F.M.H. So. to Park Ave.	20	X		X	371'		Very heavy roots	3	8	
4/19/39	Windsor Ave. from So. Village to a point half way to Park	20	X		X	345'		Very heavy roots	3	8	
4/20/39	Windsor Ave from a point half way bet.Village,Park to Park	20	X		X	345'		Root condition - not bad	3	8	
4/20/39	Center Ave. from Park Ave to Village Ave.	20	X		X	655'		Bad root condition	3	8	
4/21/39	Lincoln Ave. W/S from Lincoln Court to So. Village Ave	20	X		X	165'		Light roots	3	8	
4/21/39	So.Village Ave. from Lincoln Ave. down to Windsor	20	X		X	922'		Heavy root growth bet Lincoln Ave &			
4/24/39	W/S Lincoln Ave from So.Park to Lincoln Court	20	X		X	470'		Center Ave line partly clogged with sand Light roots-line very sluggish	3 3	8 8	
4/24/39	Lincoln Ct. from Lincoln Ave to P.R.W. to So. Village Ave	20	X		X	750'		Light roots-Lincoln Ct..Sewer opposite			
4/25/39	Center Ave. from So.Village to Merrick Road	20	X		X	767'		Lincoln Inn,filled with grease Light roots near Merrick Road	3 3	8 8	
4/25/39	Lincoln Ave. W/S from Merrick Rd. to So.Village Ave.	20	X		X	558'		Heavy root growth near Petitts Bros.	3	8	

COST PER OPERATING DAY - PLANNING - ADMINISTRATION AND SUPERVISION AND LABOR $ 25.00

Page from Maintenance and Repair Log Book, Revealing Records Kept

W. & S. W. — REFERENCE & DATA — 1946



Type of Top Root and Knob Which Calls for a Positive Cutter Here the water pressure driven cutter does the job.—See Text.

always be justified. The use of castiron house connections will eliminate much grief for all concerned.

The policy as to sewer connections lays with a governing body of a community, and it is the duty of an officer of a department to bring forcibly, and with clarity, any constructive measures that he recommends. If this is done, he has done his duty to himself and the taxpayer. It is his duty then to carry on to the best of his ability.

One of Our Pets

A prize root which tore away, leaving a five-finger knob on the top inside of pipe —see sketch—which was still a stoppage producer.

Pump Stations

The pump station is the central point to which all gravity lines feed, and it puts us in mind of a large city into which everything pours and straggles, and with positive energy must clear itself to survive. And so in our pump stations, consideration must be given to what comes in and to what extent we must go to dispose of it. The very mention of a pump station brings to us the fact that there is equipment to be considered. Screens, be they bars or baskets or mechanical grinders, have to be kept clean and the mechanism has to be checked regularly for lubrication, wear and tear. Pump and motors should be inspected regularly as to alignment, lubrication—changing old oil and grease at least once a year. Check pumps for clogging, also condition of packing. Pumps should be taken down at least once every five years, if they have run that long without trouble. In that way parts may be replaced at your pleasure and not at some inconvenient time, as an emergency. The conditions under which a pump works more or less determines the time for inspections.

Chlorinating equipment should be inspected for leaking joints; exposed parts should be covered with vaseline; strainers and other parts that clog with salts should be inspected as often as necessary. Under ordinary conditions once every three months is sufficient. Chlorine causes considerable trouble to electrical equipment and the two should never meet. Newly designed stations have a complete separation of the chlorine room from other parts of the building.

The well into which all the sewage flows should be kept clean for at this point sludge and grit settle out and putrifaction and odors set up which become a nuisance to surrounding properties. Daily flushing of a well is the most efficient way of keeping it clean. Any solids or grit which have settled can easily be flushed away with an inch and a half hose and nozzle. While considering the adjacent property owners, it is well to consider the beautification of the grounds and maintenance of the inside and outside of the building. The care of pump stations, if there are enough of them, warrants a utility man whose job it is to keep them in condition.

Costs

The cost of this type of maintenance shows an excellent economy in the form of a satisfied public, and also in dollars and cents. The equipment needed for effective maintenance totals some $2,700, and we plan on replacement every three years. Depreciation and interest runs the equipment cost to about $900 per year for our system. To this must be added $25 per day for 150 days per year to cover planning, administration, supervision, labor—say $3,750 per year.

Based on a coverage of 26 miles (137,280 feet) the cost per foot of sewers cleaned and maintained is—

$$\frac{(150 \text{ days} \times \$25) + \$900}{137.280 \text{ ft.}} = \$0.34 \text{ per foot.}$$

To cover liability, other insurance, and miscellaneous items such as gasoline, water used, etc. The cost may run to 4 cents per foot maximum.

Summing Up

The old method of sewer maintenance, which usually amounted to keeping the fingers crossed until the next call for help is made—then digging up the streets, making repairs, refilling and repaving, resulting in disgruntled taxpayers—is very expensive as against an orderly economic sewer maintenance program. At least such has been our experience in Rockville Center.

THE AMERICAN BRASS COMPANY

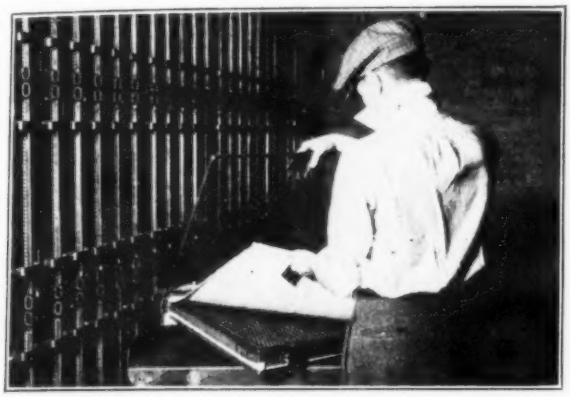
General Offices: WATERBURY 88, CONNECTICUT

ANACONDA
from mine to consumer
REG. U.S. PAT. OFF.

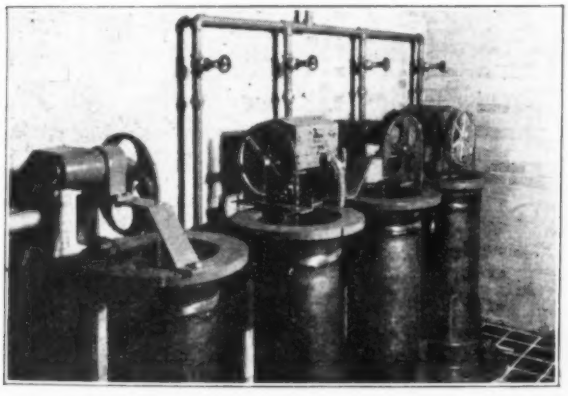
Everdur Metal

For Sewage Treatment Equipment, Reservoir and Water Works Service

FOR SEWAGE TREATMENT EQUIPMENT



Air filter of secondary room of the Ward's Island Sewage Disposal Plant. Framework of filter structure and filter holders are welded and bolted Everdur Sheet and Strip. Retaining mesh for filter is perforated Everdur Sheet. Fabricated by American Filter Co., Inc.



Control mechanicism of 12" diameter Everdur float tubes. Designed by Krajewski-Pesant Mfg. Corp. for the Ward's Island Sewage Disposal Plant, New York City.

Everdur* Metal, The American Brass Company's copper-silicon alloy, is offered as one of the most versatile materials available for the fabrication of sewage treatment equipment. It has given superior service in this field for more than eighteen years.

Everdur, made in several types, consists essentially of copper and silicon, with controlled additions of other elements. The tensile strength, in wrought form, ranges from a minimum of 50,000 lbs. per sq. in. for annealed tank plates to approximately 100,000 lbs. per sq. in. in cold worked forms. Everdur alloys all possess high fatigue resistance and resistance to corrosion equal to or better than pure copper. There are Everdur alloys adjusted for hot working and for cold work, and, with two exceptions, these metals are readily welded by either the oxy-acetylene torch or the carbon arc.

Applications

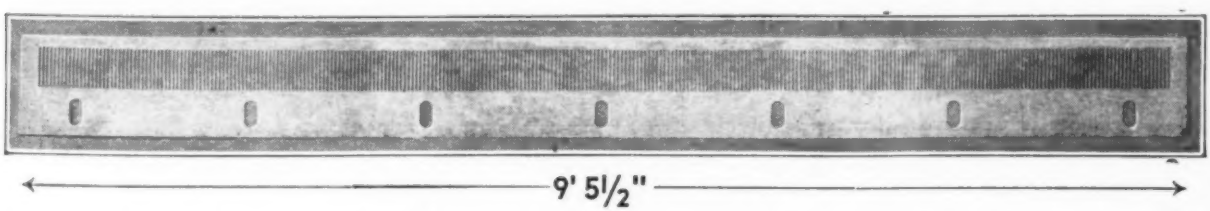
The principal applications of Everdur for sewage treatment are as follows: coarse and fine screens, swing gates, built-up sluice gates, coarse bar rack aprons, effluent weirs and scum weirs, scum baffles and brackets, troughs, screen hoppers, orifices, baskets, anchors, ladders, float gage chain, valve springs, manhole steps, walkways, bars and plates, bolts and nuts, Electrical Metallic Tubing and Rigid Conduit.

Advantages

Because of its high strength, corrosion-resistance and weldability, Everdur has effected considerable economies in equipment previously made of heavy iron castings. Relatively lightweight wrought sheets of Everdur, assembled by welding, provide much lighter, more easily operated, and more durable equipment.

Everdur Metal costs less than most high strength corrosion-resistant alloys, and not only meets many of the definitely determined corrosion problems of sewage treatment, but also provides the necessary additional protection where the forces of corrosion are variable.

*Everdur is a trade-mark of The American Brass Company. Registered in the U. S. Patent Office.

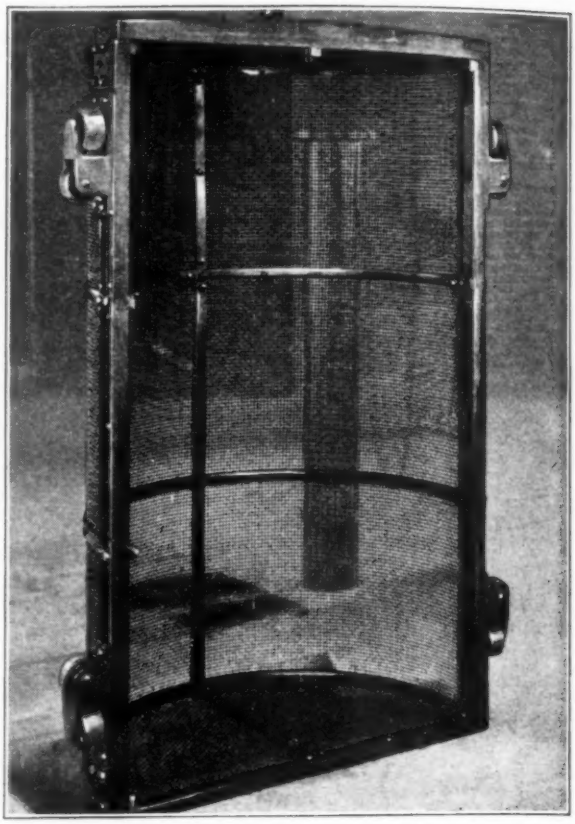


More than 100 of these Everdur weir plates, 3/16" thick, were installed in the concrete treatment tanks of the Coney Island Sewage Treatment Works. The 3/16" slots are 4" long, milled on ⅜" centers and relieved on the underside. Plates are anchored with 1" x 2½" Everdur bolts.

THE AMERICAN BRASS COMPANY

FOR RESERVOIR AND WATER DISTRIBUTION SYSTEMS

Everdur Metal is performing highly satisfactory service as an engineering material in reservoir and water distribution systems. Convincing evidence of the superiority of Everdur for water handling equipment lies in the fact that it had been adopted before the war by the majority of manufacturers of automatic domestic water heaters as the standard tank material for rust-proof tanks.



Everdur copper-silicon alloy screen frame in the gatehouse of a New England water company.

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EXPERIENCE IN SEWER MAINTENANCE*

By W. H. WISELY

Exec. Secy. and Editor, Federation of Sewage Works Assns.

THE practices and experiences presented in this article were contributed by the following, whose cooperation is gratefully acknowledged:

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Of all sewage works operation functions, that of sewer maintenance is usually considered the least pleasant and interesting, yet it is of utmost importance. There is somewhat of an inclination to neglect this essential "chore" in many cases even though the hazards of basement flooding and other effects of faulty sewer operation are appreciated. Good will that has been carefully built up by painstaking public relations activity can be easily destroyed in this way.

Maintenance Program—Records and Inspection

The most important item of equipment in any sewer department is a master map of the system, supplemented by larger scale sectional maps on which are shown important details such as direction of flow, exact manhole locations, sewer sizes and slopes, house connections, etc. Phelps (San Diego) has found that good maps save time and minimize damage to streets and private property, and recommends that all extensions to the system be plotted as made so that the reference maps will always be up-to-date. At Rockville Center, N. Y., Anderson[1] keeps a card index for permanent notes and a log book for daily maintenance notes, both of which are indexed to the sectional maps. The log book is kept by the field crew and records the location of work, conditions found, equipment used and daily costs.

Practice as regards frequency of routine inspection varies widely. Several contributors report that inspections are made only as difficulty arises, while others confine routine inspection to those sewers which have given trouble previously. A number of those reporting this inspection practice indicate that lack of personnel obviates a regular schedule.

Most general inspection practice appears to be as follows: sewers on flat grades or previously troubled by roots—every three months; sewers in which no trouble has been recorded—once to twice yearly; main intercepting sewers—one to four times per month; flush tanks—every month; inverted siphons—one to four times monthly; storm water overflows—during and following heavy rains. Some larger cities maintain a trained inspection crew which is continuously engaged in following a prepared schedule.

Anderson[1] warns that a casual glance into the manhole does not constitute adequate inspection. Steelman (Ocean City) advises inspection of critical sections during peak flows, which advice is substantiated by experience at Urbana-Champaign, Ill., where an 18-inch interceptor appeared to be flowing freely during numerous dry weather observations but was found to be carrying only 25 per cent of capacity when surcharged at the upper end during a very wet season, due to an unusually bad root condition. "Lamping" a section, by looking through the sewer during low flows toward a flashlight (explosion proof) held at the next manhole, is a common method of inspecting lines of 12-inch diameter and larger. Superintendent Case (Merchantville-Pennsauken, N. J.) employs an inspection crew of three men who ascertain the condition of the line by observation at the lower manhole while the line is being flushed or probed with light rods. A change in the color or solids content of the flow will indicate an accumulation. At Birmingham, Mich., the condition of lateral sewers is ascertained whenever an opening is made for a new house service connection.

Where a program of routine cleaning "whether they need it or not" is possible, it is usually correlated with the inspection schedule. At Cimarron, Kan., City Engineer R. R. Crusinberry has developed a schedule of routine cleaning that enables coverage of the entire system every year. At Rockville Centre, where there are 78 miles of sewers, Anderson[1] has planned to clean 26 miles of sewer each year, thus covering the entire system every three years. The work is carried out from March 15 to July 1 and from September to November, totalling about 150 days of the most suitable weather. Work in the business district is done between 4 a.m. and noon to avoid heavy traffic. A similar 3-year schedule for cleaning trunk line sewers, involving work on about 33 miles of sewer per year, has been developed by Superintendent George D. Carpenter at Ithaca, N. Y.

Baltimore, Md., has a well organized plan for continuously servicing the 1,900 miles of sewers and drains in that city.[2] Five crews of three men each are assigned to definite territories and are equipped to clean street inlets and manholes, approximately 1,200 to 1,500 being cleaned weekly. Four crews of five men each are equipped for servicing house connections and small laterals and are constantly engaged in this work. One six-man crew is equipped to work on large sewers and drains. The plan affords continuous maintenance, minimizing complaints and inconvenience to property owners.

Twenty-nine well equipped field crews are able to completely cover the 2,800 miles of sewers in Los Angeles, Cal., twice each year by working according to a systematic plan.*

Any routine sewer cleaning program must be arranged to allow for interruptions for emergency calls.

Sewer Maintenance Equipment

The size and type of sewers to be serviced, of course, determine largely the nature of equipment required, but certain items are essential to any efficient crew. Sanitary sewers will usually be troubled mostly by roots and grease, while combined or storm sewers will nearly always accumulate grit and are most likely to receive miscellaneous debris. The equipment carried by the maintenance crew will be most adapted to the character of stoppages anticipated but there must also be equipment for handling the unexpected.

A typical list of essential equipment carried by a full-time, large city maintenance crew working on all types of sewers has been developed from data furnished by the contributors to this article:

Major Equipment

- 2½ ton truck
- Power winch
- Portable, manually-operated winch
- 1,000 feet flexible steel cable
- 1,000 feet fire hose
- 600-800 feet flexible rods (power drive desirable)
- 500 feet interlocking wood sewer rods
- Root cutters of assorted sizes
- Sewer brushes of assorted sizes
- Sand buckets, scoops and drags of assorted sizes
- Turbine flushing heads
- Steel sewer tapes and heavy wire (for small sewers)
- Sewer flushing bags

Minor Equipment

- Shovels, picks and mattocks
- Assorted wrenches
- Hydrant and manhole tools
- Flash lights (explosion proof)
- Rubber boots, coats and gloves
- Buckets and rope

Safety Equipment*

- Hydrogen sulfide detector
- Carbon monoxide detector
- Combustible gas indicator
- Wolf safety lamp
- Hose mask (double) with safety harness

*From "The Operator's Corner," Sew. Wks. Jour. 14, 410, 1942. Reprinted by permission of the Federation of Sewage Works Associations.

*A combination combustible gas indicator, oxygen deficiency lamp, and toxic gas detector is available on the market.

Safety belts (2 or 3)
Complete first aid kit
Manhole guard rails
Traffic signs and flags
Oil lamps and flares

Commenting on the above list, the power winch for pulling scoops, brushes or buckets may be provided for in several ways. There are several excellent portable power units (Fig. 1) available, specifically designed for sewer cleaning, in which the engine, cable reel (with control clutch) and pulley frame are mounted on wheels and can be moved about as a trailer. At Champaign, Ill., the winch is mounted on the truck and is powered by the truck motor.

The sewer service crew of the Joint Meeting Sewer Commission of New Jersey is equipped with several unusual items which have proven highly useful.[3] A short-wave radio receiving set keeps the crew in contact with headquarters regardless of their location about the large area in which they must work; a portable platform derrick expedites heavy loading jobs and is used to transport the sewer cleaning winches; a portable, 1,500-watt generator supplies current for floodlights used in night work and for the portable air blower employed in ventilating sewers and manholes as a safety measure. Portable generators are also carried on some of the sewer maintenance trucks used at Los Angeles.[9]

The sewer maintenance departments of cities of moderate and small size are seldom equipped as completely as listed above, despite the fact that the best of equipment yields greatest economy. Commonly, the general purpose city truck is used to transport loose equipment or pull a small trailer. The truck is sometimes used to pull scoops, drags or brushes as a substitute for more suitable power machines. There is also an unfortunate tendency for small city crews to work without adequate safety equipment and fatal accidents in such crews are much too common. Phelps (San Diego) suggests that the cooperation of the local gas company be obtained when special testing equipment is required for occasional gas surveys.

Character of Sewer Stoppages

The most common obstructions in sewers, in the order of greatest incidence, are (1) roots, (2) accumulations of grease, (3) grit and (4) miscellaneous debris.

Roots generally enter at faulty joints. Growth usually occurs from a single leader root which continues developing inside the sewer until branches from the leader often fill the entire pipe. Phelps reports one root growth 30 feet in length (Fig. 4) removed from a sewer in San Diego. An unusual root removed in San Diego is shown in Fig. 5. Care in making joints, use of proper jointing materials and careful tamping of backfill during sewer construction are good insurance against root troubles later.

Copper, toxic to most plants, has been employed to control root growths. A copper ring, made for the purpose, is available for placing in the joint at the time the sewer is laid. Killing of root growths in sewers by copper sulfate is successfully practiced at San Diego, Cal., and Greenville, Tenn., and elsewhere, a handful of blue vitriol crystals being dropped into a manhole above the suspected root growth, while flow is taking place. Repeated applications may be necessary to kill the leader growth, which later break loose due to the water pressure behind it.

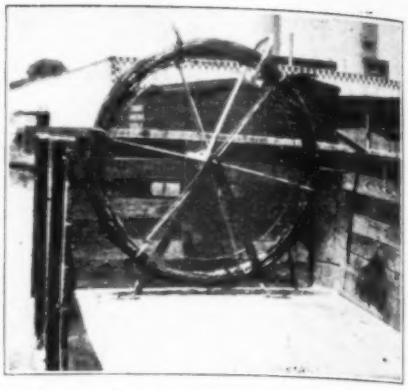

Fig. 2—Method of Using Flexible Sewer Rod Reel in Truck.

Superintendent Case of Merchantville, N. J., reports most root troubles caused by poplar and willow trees and these are removed where difficulty has been caused, to prevent recurrence.

Grease accumulations on the inside of the sewer and in the form of floating balls is a major problem at Atlantic City, N. J.,[4] and other places. Ordinarily discharged to the sewer with hot or warm water, the grease congeals as it cools and adheres to the walls of the sewer or develops into a ball with some small particle or object as a nucleus. These accumulations continue to build up until they materially reduce the capacity of the sewer.

Grit in the form of cinders, ashes, sand, mud, etc., which enters combined and storm sewers with surface water run-off and sanitary sewers with basement drainage, is often troublesome, particularly where sewers are on flat grades. At Rock Falls, Ill., and elsewhere, unpaved streets are the source of excessive grit deposits in sewers. Sewers laid through quicksand often shift due to the unstable foundation, opening at the joints and permitting the fine sand to enter. This condition is serious at East Aurora, N. Y., and, to a lesser extent, at Ocean City, N. J. Mud and sand originating at automobile wash racks is reported to be a cause of grit accumulation in sewers at Kahoka, Mo., and Cimarron, Kan.

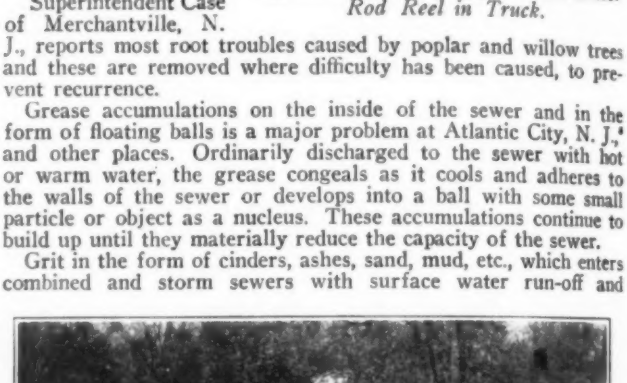

Fig. 3—Power Driven Sewer "Drag" Mounted on Trailer at Ithaca, N. Y.

The character of miscellaneous debris removed from sewers (combined and storm drains in particular) is almost unimaginable. Barrels, posts and a bed spring are on the list at Bloomington-Normal, Ill., and a washing machine was once removed from a large line at Springfield, Ill. Removal of some of these articles demands much ingenuity and patience on the part of sewer maintenance personnel.

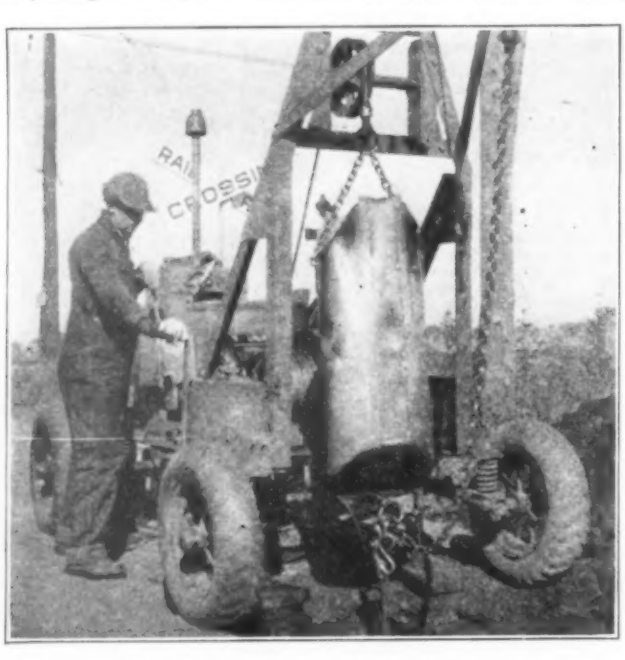

Fig. 1—Turbine Sewer Cleaning Machine at Bloomington, Ill.

Sewer Cleaning

Flushing.—Although not always positive, flushing of sewers is a convenient method of scouring out minor grit deposits and grease accumulations.

Surface water discharges during rains provide adequately for flushing storm and combined sewers, although supplementary flushing by fire hose is employed at Birmingham, Mich., Portland, Ore., and Sacramento, Cal., in conjunction with other cleaning operations, to clean lateral lines and to reduce odors at manholes in extended dry weather seasons. Routine flushing is a general practice in maintaining separate sanitary sewers but the frequencies reported vary from monthly to annually. At Orillia, Ontario, where the sanitary sewers have a minimum

slope of 5 per cent, Engineer L. G. McNeice indicates that annual flushing is practically the only maintenance required. In some cases, as at Ithaca, N. Y., and Kahoka, Mo., routine flushing is limited to critical lines on flat grades, which are flushed every two or three weeks. At Kahoka, some shallow lines are flushed after midnight by means of a time-clock actuated electric valve on the water service, giving a discharge of twenty minutes' duration.

Many old sewer systems were equipped with automatic flush tanks, located at the upper ends of laterals to assure scouring of deposits. Present practice is to design sewers with adequate slopes and the use of such devices is confined to lines in which flat grades are unavoidable. A number of contributors to this article indicate that old flush tanks have been abandoned; others that they are still used occasionally.

From a practical study of the hydraulics of sewer flushing, Watson[8] concludes that the *depth* of the flushing flow in the sewer is equally as important as the velocity. This accounts for the fact that flushing is most effective when the sewer is plugged at the lower manhole, the fire hose used to loosen grit deposits and grease accumulations and, after a head of sewage and water is built up, the plug is suddenly removed to release the flush. Kilpatrick (Rolla, Mo.) emphasizes the importance of blocking the sewer in connection with flushing operations. Sewer "bags," having a hose connection at one end and a nozzle in the other, are available for plugging the sewer and adding flushing water at the same time.

Satisfactory flushing by means of "water wagons" is accomplished at Los Angeles[9] and Lower Merion Township, Pa.[10] In the latter case, water is discharged at the upper manhole from a 625-gallon steel tank mounted on a truck and having a 6-in. drain valve. Discharge is so rapid that an 8-in. sewer is completely filled, giving an effective flush of 500 to 800 feet of sewer.

Hydrogen sulfide formation in sewage is accelerated by the presence of septic sludge deposits in sewers. Bowlus[11] reports that sulfides are definitely reduced after flushing, indicating that the practice is beneficial in reducing odors at manholes and treatment works as well as in reducing damage to sewers and concrete structures.

Removal of Roots.—For cutting and removing root growths in sewers up to 15 in. in diameter, flexible type rods and cutters appear to be very popular, because of the time saved, compactness of the equipment and small labor requirement. An augur-like cutter is used, which is rotated by twisting the rods as they are forced down the sewer. The equipment can be operated easily with two men if the power drive is used, or four men if the rods must be twisted manually. Another advantage of this equipment is that it can be fed into the sewer from ground level and does not require entry into manholes. Accumulations of roots removed at Cimarron, Kan., are shown in Fig. 6.

For removing roots from larger sewers, or particularly obstinate ones from small sewers, cutting drags are pulled through by cables and winches, either power or manually operated (Fig. 7). This procedure is positively effective, and in many cities is the only method used.

At Ocean City and Merchantville, N. J., every effort is made to prevent recurrence of root growths which are removed from sewers. Steelman at Ocean City reports that defective joints admitting roots are immediately located and repaired and some very troublesome lines have been relaid in iron pipe. Poplar and willow trees causing trouble at Merchantville are removed. Permanent control of roots in house service lines is the aim at Birmingham, Mich., where the city provides 6-in. cast iron pipe with leaded joints to the property line and requires not less than vitrified pipe with asphalt mastic joints inside the property. In case of root stoppage in old cement jointed vitrified pipe services (in the street), the city relays the service to the property line in cast iron pipe for a permit fee of $15.00.

Removal of Sand and Grit Deposits.—When flushing does not produce adequate results, sand buckets or scoops pulled through by the cable and winch outfit are universally depended upon for removing deposits of grit. This equipment (Fig. 1) is positive in effectiveness, regardless of the size of the accumulation.

Where the deposit is not too large, the "Turbine" cleaner which has a water powered, rotating cutter is effective. This device, dragged through the sewer by cable and winch, combines water jet flushing, cutting and dragging into one effective operation.

Rawn[7] describes an ingenious sewer "hoe" used by the Los Angeles County Sanitation Districts for removing grit accumulations from sewers over 30 in. in diameter with a minimum of labor. The device is propelled through the sewer by the pressure of sewage behind it and the invert and sides of the pipe are scoured as it moves. For sewers of 15 to 30 in. in diameter, a beach ball inflated to approximately the size of the sewer is used effectively in the same fashion as the "hoe."

Removal of Grease Accumulations.—Unless of industrial origin, sewer stoppages by grease are confined almost entirely to house services; however the capacity of larger sewers is often reduced due to the development of a grease lining in the pipe.

Flat sewer tapes with various kinds of cleaning tools are used for removing grease obstructions from house connections at Ocean City, N. J. Large sewers give no trouble here. At Atlantic City, N. J.,[8] the most useful device for opening house

Fig. 4—A Few Roots from a San Diego Sewer.

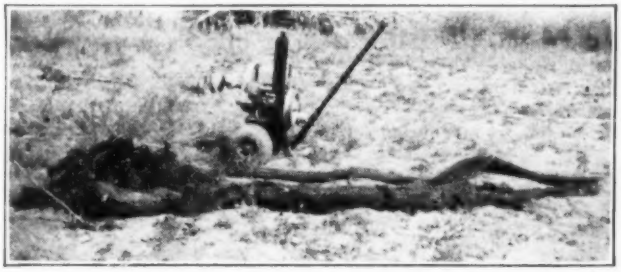

Fig. 5—Not a Sea Monster—A Root Removed in San Diego by Power Driven Flexible-rod and Cutter.

Fig. 6—Root Removed by Flexible Sewer Rod Equipment at Cimarron, Kas.—City Engr. Cruisinberry at Right.

connections has been found to be a 50-ft. length of quarter-inch steel wire. The end started into the sewer has a 6-in. bend which is rotated by cranking the other end as the wire is fed, thus gouging out the stoppage.

Grease accumulations in larger sewers are loosened to some extent by flushing, root-cutting and other maintenance operations. Sewer brushes, dragged through by the ever useful winch and cable equipment, are most positive, however, and many well-trained crews always use a brush drag to finish up a line that has been dragged with other tools.

Other Cleaning Devices.—It will be noted that certain types of equipment are best suited to specific cleaning problems, yet it may often be necessary to use practically all of the equipment carried for cleaning a single line. For instance, the flexible rod and root cutter and/or detachable wooden rods may be used to partially open a stoppage to permit a cable to be threaded through for use in dragging, and several types of drags may be employed. Unusual situations will often demand considerable thought and ingenuity on the part of the maintenance crew even though they are well equipped for ordinary problems.

The sewer "hoe" and beach ball cleaners described above are examples of such ingenuity. The Los Angeles County Sanitation Districts, where these labor-saving implements were devised, makes root cutting drags for 12 to 36-in. sewers from steel pipe[7]; sewer brushes at Ithaca, N. Y., are made from old street-sweeper brooms; a knot of old chain has been found to constitute a serviceable root cutter and drag at Portland, Ore.; a 15-in. root cutter was made to service an 18-in. sewer at Urbana-Champaign, Ill., by wrapping the periphery with barbed wire, further illustrating actual practice in meeting local problems.

Ground Water Infiltration

Although most ground water infiltration results from faulty sewer construction (poor joints or failure to use proper pipe through critical water-bearing soil formations), good maintenance and operation practices can reduce this problem. In referring to infiltration, nearly all of the contributors to this article mentioned the relatively new asphalt mastic jointing compounds as a curative measure, either in explaining why there was no serious infiltration problem or describing how it is being minimized in new extensions or old sewer repairs.

Where there is ample sewer capacity, gravity flow and no sewage treatment works, there is an inclination to disregard infiltration to some extent. Usually the allowance for infiltration in the design of separate sanitary sewers is only nominal but such leakage often proves to be of serious consequence, as at Ithaca, N. Y., where it amounts to 100 to 400 per cent of the dry weather sewage flow due to broken pipe and poor joints. Superintendent Carpenter indicates that correction can be accomplished only by replacement of the defective lines by cast iron or other suitable pipe.

Where sewage must be pumped, it has been found economical to locate and actually replace those lines admitting large amounts of ground water. This has been done at McHenry and Fox River Grove, Ill., Rolla, Mo., and elsewhere.

Steelman (Ocean City, N. J.) and Bridges (Kahoka, Mo.) point out the necessity of careful control and inspection of house connections to minimize infiltration. The sharp increase in flow in sanitary sewers during rains is usually caused by illicit downspout connections which are most difficult to control since many of them are changed after the installation inspection is made. Constant vigilance, public education and rigid enforcement of ordinance provisions are the only possible means of minimizing this source of extraneous water. Kahoka, Mo., and Birmingham, Mich., sewer users are required to comply with strict specifications for workmanship and materials in constructing house sewers.

Maintenance of Appurtenant Sewerage Structures

Aside from ordinary inspection and replacement of broken manhole covers, it is important that manholes in unimproved or semi-permanent streets be maintained at the proper elevation. Considerable damage to such streets is done when an attempt is made to find a manhole which has been covered. Rattling manhole lids often create a nuisance and correction has been accomplished by: application of tar or asphalt around the entire rim or at three or four points[10]; gaskets of rubber, jute or canvas; machining of the lid and casting; use of mechanical locking lids or low center of gravity types. Anderson,[1] after trying several methods, now uses a tape packing made for the purpose which is placed around the entire periphery after thorough cleaning of the casting.

Other appurtenances common to separate sanitary sewers are inverted siphons, creek crossings and flush tanks. Inverted siphons must be inspected frequently as they are readily clogged by accumulations at the inlet or grit deposits in the siphon pipes. Two siphons on intercepting sewers at Champaign-Urbana, Ill., are inspected at least weekly and cleared of inlet accumulations. Three siphons at Ithaca, N. Y., are flushed out every four months. Creek crossing structures are generally checked following wet seasons to ascertain erosion damage, replace protecting rip-rap or make repairs. Flush tanks maintained in regular service are inspected monthly and afforded cleaning and adjustment.

Frequent cleaning of catch basins on storm or combined sewer systems is justified by the protection they provide against grit deposits in the sewers. Practice appears to be to clean these at least annually where paved streets are drained and more often when streets do not have a permanent surface. Street inlets are inspected and cleared after every rain at Rock Falls, Ill., to assure good street drainage. Storm water overflows are inspected and given necessary attention at least once monthly at Birmingham, Mich., and Bloomington, Ill., with more frequent attention being accorded in wet seasons. Sewage flow regulators and adjustable overflows in combined systems are best attended during high flows so that they may be adjusted to actual operating conditions.

Regulation of Use of Sewers

Probably no other public utility is misused to so great a degree as is the sewer system, yet there is always readiness on the part of the public to criticize faulty operation. This condition is no doubt largely due to the lack of public education and to the failure of city officials to adopt and *enforce* proper ordinances controlling the usage of sewers. Such an ordinance does no good if merely filed among the dusty archives of the municipality—it must set forth proper practices, contain adequate penalties and be enforced without hesitancy when courteous requests for cooperation are ignored.

Anderson[1] points out that the best way to obtain public cooperation is to definitely allocate responsibility for house sewer connections to the property owner, requiring him to pay for any maintenance work necessary on these lines. Many eastern cities have established a policy of accepting responsibility for all sewers outside the curb, which practice appears to have several advantages. The Atlantic City Sewerage Co.[8] requires a trap on each house service at the curb and responsibility in each case is determined by examination of the trap. The company services all sewers outside the curb and local plumbers perform at the property owner's expense any work needed from the curb to the house.

Among the more important items warranting inclusion in the sewer ordinance are:

1. Control over location of certain trees (poplar and willow) which might cause root stoppages, including authority to remove such trees found to cause trouble.
2. Prohibition of downspout and similar surface water connections from separate sanitary sewers.
3. Provision for detailed inspection by competent personnel of all house service installations. Also rigid specifications covering workmanship and material in house services.
4. Requirement of suitable preliminary treatment facilities in commercial and industrial concerns to prevent damage to sewers. Wastes commonly controlled for this purpose are: (a) Greasy wastes from restaurants, packing plants, etc.; (b) oil and dirt from automobile filling stations and wash racks; (c) Inflammable and explosive wastes from cleaning establishments; (d) wastes containing excessive solids, such as spent grain from breweries, paunch manure from packing plants, ashes, garbage, etc.; (e) corrosive wastes, as those from metal galvanizing and pickling plants.
5. Requirement of suitable preliminary treatment facilities in industries to prevent interference with sewage treatment plant operation.
6. Provision for stern penalties for malicious damage by vandals.

A combination grit and oil trap recommended by the South Dakota Board of Health[9] for use on sewers from garages, filling stations and automobile wash racks is shown in Fig. 7. The oil problem is successfully met at Baltimore[3] by requiring by ordinance that such waste be stored on the premises until collected periodically for disposal under direct control of municipal authorities. The provision of a convenient means of disposal of the oil eliminates need for policing garages and similar establishments.

After a bad fire caused by waste oil and gasoline dumped to sewers at Aurora, Ill., Superintendent W. A. Sperry acted to prevent a recurrence by means of newspaper publicity and direct contact with industrial sources of volatile wastes. The latter was accomplished by a plant-to-plant canvass of 245 industrial and commercial establishments, during which a verbal notice

was given a responsible representative of each concern, a poster epitomizing the sewer ordinance was left and a signed acknowledgement of each visit was obtained. The survey cost $100 and appears to be good insurance against future damage, although it must probably be repeated after several years.

Sewer Ventilation

Ventilation in sewers is necessary to dilute and purge the system of gases which are inflammable, explosive, asphyxiant and toxic. In warm climates where hydrogen sulfide is often a problem, ventilation is also beneficial in controlling disintegration of concrete sewers and structures because (a) the concentration of H_2S in the atmosphere and (b) collection of moisture on exposed surfaces, are reduced.

The degree of effective ventilation in a sewer is usually dependent upon the amount of vent openings and the movement of air across the openings. Thus, it appears that natural ventilation is at a minimum on still days.

Forced ventilation has been found justified in large outfall sewers at Los Angeles[9] and several ventilation stations are in development. Ordinary ventilation practice is probably represented by the procedure at Lower Merion Twp., Pa.[10] "Ventilating covers" having eight 1-in. openings are placed at the upper ends of all lines and approximately at each third manhole, with consideration being given to surface water drainage and proximity to points at which odor might be troublesome, when selecting locations. Buckets are hung beneath ventilating covers for the purpose of catching debris which might pass through the openings.

To guard against fires and explosions and to eliminate conditions dangerous to sewer maintenance personnel, the city of Los Angeles[9] has a gas survey crew which systematically checks the entire system, making observations at about 60,000 manholes per year. Results of various gas detector tests are recorded and used as basis for correction of dangerous conditions. When the presence of illuminating gas is suspected, the utility company is immediately notified so that any gas main leak may be repaired.

Design and Construction Items Facilitating Maintenance

Good design and careful construction of a sewer system will reduce maintenance to a minimum and expedite such work as is necessary. There has been sufficient experience at this time to substantiate present methods of ascertaining sewer sizes and grades, yet there is often a tendency to violate the limitations of good practice, particularly with respect to grades. Every effort to avoid capital and operating costs of pumping stations is certainly justified, but consideration must also be given the less satisfactory service and everlasting maintenance expense which accompany the installation of sewers on flat grades. Where moderate reductions in slope are logical, provision of adequate, suitable flushing facilities constitutes good practice.

The prevalence of difficulties from roots and ground water infiltration is ample proof that too much care cannot be taken in specifying and installing permanently tight joints. This fact, of course, is generally appreciated and modern jointing methods and materials are already demonstrating their superiority. Careful specification and performance of back-filling is also important in preventing crushing of pipe and movement which results in opening of joints. The use of especially suited pipe and construction methods in sections where foundation conditions are bad or where excessive ground water is present, has been proven to be good economy, even though more expensive in first cost.

Other design and construction details suggested by maintenance personnel as being of importance to their functions are the following:

1. Design of junction chambers so that back-water areas of low velocity, causing deposition of grit, are avoided.
2. Design of storm water overflows so that they are not accessible by vandals.
3. Catch basins of ample size at storm water inlets draining unpaved streets.
4. Complete consideration of local conditions when selecting the type of pipe used for sanitary and industrial sewers.
5. Spacing of manholes not more than 350 feet apart.
6. Lateral sanitary sewers of not less than 8 inches diameter.
7. Smooth flow without splashing or turbulence at manholes or appurtenant structures. (Important where hydrogen sulfide might be a problem.)
8. Diversion and regulator devices of simple design and capable of convenient adjustment.

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Fig. 7—Manually Operated Sewer "Drag" in Ithaca, N. Y.

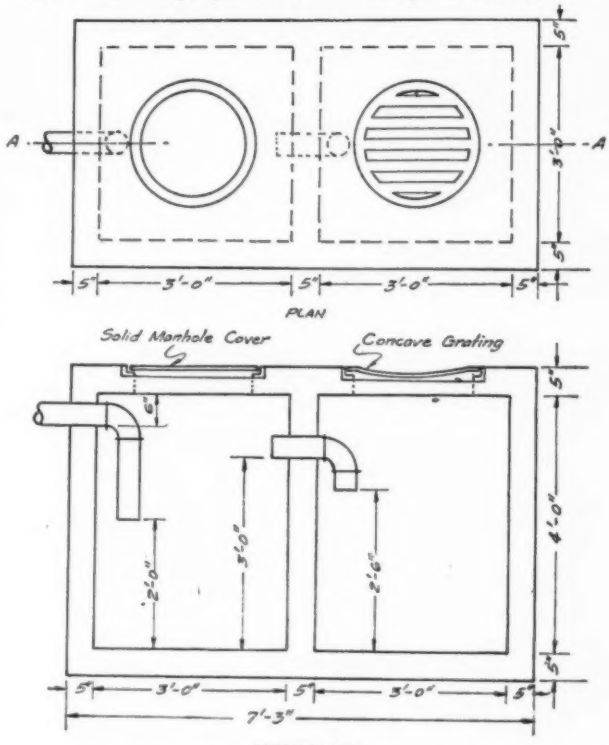


Fig. 8—Combination Oil Trap and Grit Basin for Garages and Filling Stations. Recommended by South Dakota State Board of Health.

SEWER FLUSHING

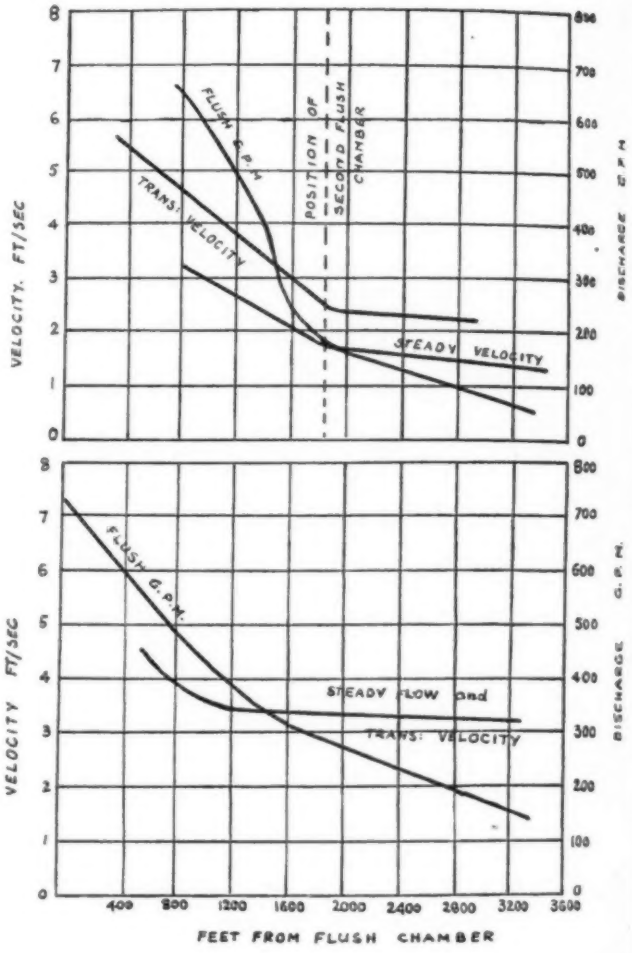
Good and Indifferent Practices

By JOHN D. WATSON
Consulting Engineer, Ruislip, England

This article reveals much pertinent to "Sewer Flushing" practices and presents what may be considered satisfactory flushing and what will prove a waste of effort and funds. The all important depth of flow in flushing, as compared to velocity flow without the needed depth, is pointedly emphasized. If we interpret correctly, many readers will find it necessary to consider some of our existing pseudo-flushing practices as little more than sewer "rinsing," after reading the depth—velocity discussion by Mr. Watson—an authority with a wealth of experience and years of observation to draw upon.

The basic condition upon which calculations for sewer flow should be made is that the sewer have a self-cleaning velocity. In other words, it should never tend to silt up even though the dry weather flow condition persists for long periods while at the same time it must be capable of taking storm water, unless it is wholly diverted from it. Provided they are properly constructed it is not usually difficult to give sewers a sufficient fall for this condition to be fulfilled. Main sewers will work with little or no trouble when laid on a grade of 1:1000 or less and, when the London Main Drainage was designed some 70 years ago, experiments showed that a velocity of 1½ miles per hour was sufficient, and very little cleaning is necessary in these sewers today. They vary from the familiar oval section of 4-ft. x 2-ft. and 8-in. to circular sewers of 12-ft. diameter. They are mainly built of brick.

Trouble is rather more likely to occur in the smaller branch sewers which have to be put in of a size to allow of increasing population so that for perhaps 10 or 20 years, normal flows are insufficient to maintain a self-cleansing velocity; and, while it is usually possible to divert surface water into them, it usually has to be kept out in order to save pumping and purification costs. The system adopted at one time at Hamburg, of constantly flushing the main sewers from a small river, enabled them to be laid at 1:3000, and to be run practically half full continuously, but that principle has rarely been adopted. The usual practice, when artificial flushing is resorted to, being either to provide gates to dam back the flow and then to release the pent up sewage for the purpose; or the use of tanks operated by an automatic syphon, the latter arrangement being as a rule the better one.



Curves Revealing Relationships Between Depth of Sewer Flush (Rate of Flush Discharge) and Effects Down-Sewer

The Great Importance of Depth in Flushing

When arranging for it the important points to bear in mind are, that the flush is not going to be effective over any great distance, and that it is the depth of flow over the invert of a sewer which is the most effective in moving the material which is the main cause of obstruction. That of course, is the condition intended to be provided by the oval sewer, silt being usually the main cause of the trouble in the present connection. In the form of road detritus, though it may reach the sewers mainly in times of storm when there should be sufficient velocity to carry it to the outfall, road detritus in the average condition has been found by experiment to require a velocity of nearly 1-ft./sec. to keep it on the move and if small pieces of broken stone and similar material get into the sewer (which by some unaccountable means they do) such, according to size, will require a velocity of 2½ to 3½-ft./sec. to move them. Incidentally, it is such obstructions in the first instance, as a rule, which cause a general obstruction to build up.

Such material always moves along with a speed of travel less than that of the stream (usually not more than half) and though 2½-ft./sec. flow velocity may move a piece of stone it will only barely do so in 1-in. depth of water. But, if the depth be increased to 6-in. it will roll along quite easily at 2-ft./sec., confirming the contention already made that it is the depth of liquid in the sewer that is the really important factor in keeping it clean. Therefore, the conclusion to be reached, is that, in circular sewers at all events and more particularly in the average branch up to 30-in. dia., the basic cause of silting is *insufficient depth* of flow *rather than velocity;* and, especially is this evident in lateral sewers which only receive intermittent discharges from the dwellings connected to them. Thus, deposits commence which ought to be periodically flushed away because if they are not removed, although they might not immediately render the sewer inactive, they cause a filmy growth (slime) to appear on the pipe wall. This growth in turn further reduces the velocity, and so matters go from bad to worse with the additional evil of the sewage becoming septic and producing large volumes of sewer gas, with its well known attendant evils.

This can be demonstrated in a simple manner by purposely putting some coarse sand or fine gravel in a sewer. Then it will be found that while motion is set up by dragging action, the particles are more or less lifted up into the stream and further motion is carried on by the added effect of suspension. The greater volume of material is naturally carried in the lower layers of the stream, the total quantity being proportional to the depth. Motion, too, will be seen to be from the sides of the sewer towards the centre, the major portion of the suspended matter being carried along the centre of the stream. The amount and the size of the material being carried in suspension

depends upon the velocity of the stream and its depth of flow. But, to a much greater extent depth is controlling, because in appreciable depth of liquid the particles are thrown to a greater height; and, as the velocity of descent of the particles is the same in both cases, the deep stream carries the particle further owing to the greater opportunity of remaining suspended.

Effects of Flushing

The conclusions to be reached, therefore, are that as a general rule it is advisable to provide means for flushing pipe sewers when they are laid at flatter gradients than those listed below:

12-in.....1:300	21-in.....1:600
15-in.....1:400	24-in.....1:700
18-in.....1:500	27-in.....1:800
30-in.....1:900	

Between 2,000 and 3,000 gallons at a flush, according to the size of the sewer and provided it is released once or twice every 24 hours, usually suffice. In any event it should be an amount that, when it does come into the sewer, practically fills it at that point. This, because the depth of the flushing wave near its point of origin decreases as it moves downstream to a point at which the depth and velocity are but little affected by the discharge. As an example, one can consider a 12-in. sewer flush by a 1,500-gallon tank through a 10-in. syphon in 1¼ minutes.

On the accompanying chart the upper set of curves relate to such a sewer laid at 1:630. One curve reveals transmission velocity, the other steady-flow velocity. As regards the former, the rate of transmission, at the commencement of the flush and at different distance from the flushing chamber, is that which would give the maximum scouring velocity, assuming the flush to be discharged into an empty sewer. This velocity lasts but a few seconds and its effect reaches but a short distance. In the matter of the steady-flow velocity, during the period when the maximum volume of flushing water is passing at different distances from the flushing chamber, it will be observed that this velocity lasted for a minimum period of 1 min., the period increasing with the distance from the flushing chamber. There is also a third curve which reveals the maximum volume of flushing water in gallons per minute at different distances from the flush chamber. From this curve, the effect of varying the amount of flush water discharged per minute can be determined. The lower set of two curves, in comparison, relates to a 9-in. sewer having a flush of 750 gallons for one minute.

Facts and Conclusions

The principal facts which become apparent from an examination of these curves are that:

(1)—The velocity dies off rapidly at first until it attains a certain value after which the diminution is small. As a result the flush is transmitted over an appreciable distance, probably about one mile.

(2)—With flat gradients, the velocity when the maximum volume of flush water is passing is less than the rate of transmission at the commencement of the flush, the difference gradually decreasing as the gradient decreases until the velocities are identical—such being indicated by the lower graph.

One can conclude, therefore, that the slope of the advancing flush will gradually flatten as the distance from the flushing chamber increases except where the gradient is sufficient to secure a high velocity. It is noticeable, also, how the steady flow velocity is over 3-ft./sec. at a distance of more than 3,400 ft. from the flush chamber. If, therefore, the sewer gradient is reasonably good, though appreciably less than that above set out, a good flush (rapidly discharged) will keep a sewer clean for at least half a mile even though its capacity be considerably in excess of normal dry weather flow requirements. And that, as already indicated, is the main purpose of artificial flushing.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. I), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

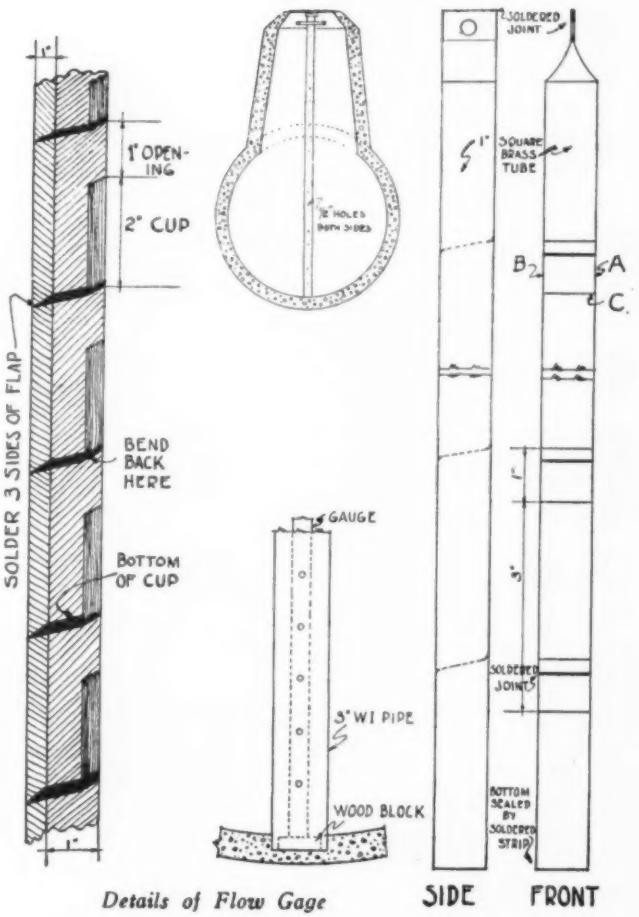
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

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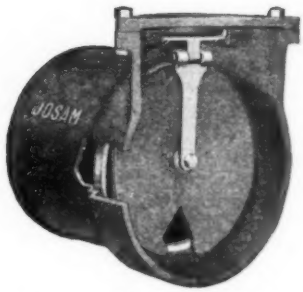

FLAP VALVE Series 1100½

When placed at the discharge end of sewer pipes, the Josam Flap Valve is an absolute safeguard against the backflow of sewage. In sewer lines it can be placed at the manhole. It will also serve as a sluice, river or tide water outlet and can be used between settling basins in sewage disposal plants.

GREASE INTERCEPTOR

The Josam Cascade Grease Interceptor provides maximum grease interception and retention for all types of installations. Grease is removed before it clogs drain lines, regardless of the temperature of the water. Made in types and sizes for any requirement.

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OIL WASTE EXCLUSION FROM SEWERS

Baltimore Experiences with a Workable Ordinance

By C. E. KEEFER
Prin. Asst. Engr., Bureau of Sewers, Baltimore, Md.

IN 1927 a fire near the outlet of the largest storm drain in Baltimore resulted from the escape of gasoline and oil into the drain. Causing no serious damage, it did, however, result in passage of a city ordinance requiring daily storage of waste oil, crankcase drainings and greases in approved steel drums by all users of such materials.

The Baltimore Ordinance No. 1083

An ordinance to regulate the handling, storage, transportation and disposition of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind upon all premises in Baltimore City; providing for enforcement, and also providing a penalty for violation of the provisions of this ordinance.

Section 1. Be it ordained by the Mayor and City Council of Baltimore, That from and after the date hereinafter provided, the following rules and regulations shall apply to the handling, storage, transportation and disposition in the City of Baltimore of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind:

(a) All waste oils, including crank case drainings, shall be immediately taken up and deposited and kept while on the premises in steel drums, the character, size construction, number and location of which shall be from time to time prescribed by the Board of Fire Commissioners of Baltimore City, or in containers of other construction approved by the Chief Engineer of Baltimore and by the said Board.

(b) All waste greases shall be collected at least once daily and deposited and kept as in the manner provided for waste oils in the preceding paragraph, and in no case shall any waste greases be permitted to remain in or about any premises over night, except when so deposited.

(c) All such drums, containers and their appurtenances shall be kept and maintained at all times in first class condition and tightly closed so as to prevent the escape of any of the contents thereof, and shall be used for no purpose other than the storage and transportation of waste oils and greases.

(d) The Mayor and City Council, acting through the Chief Engineer of Baltimore, shall determine from time to time the agencies by or through which all such drums, containers and/or the contents thereof shall be removed, stored, transported and disposed of, and the times when, the places where and the manner in which the same shall be done, and such determination shall be subject to the approval of the Board of Fire Commissioners of Baltimore City; and no such drums, containers and/or contents shall be removed, stored, transported or disposed of in any other manner or through any other agency.

Section 2. And be it further ordained, That this ordinance shall not be construed to prohibit the sale and/or reclamation of waste oils and greases, provided, on such sale and/or reclamation, said waste materials are otherwise handled, stored, transported and disposed of in accordance with the terms and provisions of this ordinance and any rules and regulations made in pursuance thereof.

Section 3. And be it further ordained, That terms used in this ordinance are hereby defined as follows:

The term "waste oils and greases" shall include all oils and greases which, by reason of previous use in and about vehicles, machinery or appliances of any kind, are in such condition as to be unfit for further use for such purposes without reclamation.

The term "premises" shall include all real and leasehold property where such vehicles, machinery, or appliances of any kind are used, operated, cleaned, repaired or serviced.

The term "person" shall include persons, firms and corporations.

Section 4. And be it further ordained, That any person violating any of the provisions of this ordinance shall be subject to a fine of Fifty Dollars ($50.00) for each and every offense.

Section 5. And be it further ordained, That the Board of Fire Commissioners of Baltimore City are hereby charged with the duty of enforcing the terms of this ordinance.

Section 6. And be it further ordained, That all ordinances, or parts of ordinances, inconsistent with the provisions of this ordinance be, and the same are hereby repealed to the extent of such inconsistency.

Section 7. And be it further ordained, That in the event that any word, phrase, clause, sentence or section of this ordinance shall be declared invalid by any court, the remainder of the ordinance shall not be affected thereby, but shall remain in full force and effect.

Section 8. And be it further ordained, That this ordinance shall take effect three (3) months after the date of its passage and approval.

Approved May 11th, 1927.
HOWARD W. JACKSON, Mayor.

Attest: A True Copy:
JOHN A. SLOWIK, City Librarian.

Collection Contracts

In order to provide for the collection of these materials the city entered into a two-year contract with a collection company. Since the first contract expired, Sept. 30, 1929, the work has been done by three companies at different times. The cost to the city is shown in the accompanying table.

During this sixteen-year period 4,287,714 gallons of oil and greases have been collected. This is equivalent to 263,860 gallons yearly at an average cost of 7.5 mills per gallon.

Cost of Collecting Grease and Oil in Baltimore from 1927 to 1943

Year	Contractor	Amount paid contractor	Grease and oil collected, gal.
1927	Provident Oil Service Co.	$ 810	71,701
1928		3,240.00	265,000
1929		3,037.50	318,000
1930		2,430.00	286,850
1931		2,430.00	280,100
1932	Thomas Leonard	2,422.50	229,299
1933		2,400.00	139,804
1934		2,400.00	143,280
1935		2,300.00	155,690
1936		2,000.00	169,515
1937		2,000.00	156,150
1938		1,625.00	120,940
1939	City Waste Oil Co.	500.00	327,440
1940		500.00	437,420
1941		768.75	473,420
1942		1,575.00	416,099
1943		1,575.00	297,006
	Total	$32,013.75	4,287,714

The contractor is required to furnish steel drums for the storage and transportation of oil and greases where the amount collected is more than 20 gallons weekly. For lesser quantities, the containers are furnished by those who must dispose of the oil or grease. Containers must be collected within 24 hours after they are full.

The present contractor has three 1,000-gal. tank trucks for the transportation of the materials. Each truck is equipped with a suction and a discharge pump for handling the oils.

Oil Purification Plant

Oil is discharged from the tank truck into an underground storage tank, from which it is pumped into a 2,000-gal. dehydrating tank containing steam coils. Moisture evaporation is accomplished by passing steam at 90 lb. pressure through the coils for a period of five to eight hours.

Dehydration is followed by sulfuric acid treatment in a 1,500-gal. storage tank. Sludge precipitated from the oil is disposed of in a lagoon. Clay is added to the partially purified oil which is then cooked with steam at about 600 deg. F. for eight to ten hours. During the cooking the higher volatile hydrocarbons such as kerosene, naphthalene, and the alcohols are distilled off for use as fuel in the steam generating plant.

The oil residue is cooled to approximately 200 deg. F. and filtered in a Shriver plate press, producing a filtrate equal in quality to new oil and ready for sale. About 12 hours are required to complete the process.

The collection and purifying of oil is not unique with Baltimore as similar plants are in operation in New York City, Philadelphia and elsewhere. The unique feature about the practice is that Baltimore has adopted an ordinance requiring daily collection and disposal of greases and oils and has made the necessary provision for having the work done. Since this ordinance has been in effect the sewers in the city have been remarkably free from inflammable materials.

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• As specialists in the design and manufacture of equipment for Water, Sewage and Industrial Waste Treatment Plants, Link-Belt engineers have learned how to apply an extensive knowledge and experience effectively, to the solution of such problems.

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STRAIGHTLINE COLLECTORS

Link-Belt STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks consist of two strands of especially processed malleable chain from which are suspended at uniform intervals scraper flights usually made from red wood. Features are peak-cap bearings, pivoted flights, cross collectors for larger tanks, and positive sludge removal at a slow, uniform speed. Automatic or semi-automatic skimming equipment is furnished when required.

Many installations are now in service in all parts of the country and range in size from the smaller type plants as at Tappahannock, Va., with a capacity of 80,000 G.P.D., to larger installations, such as Ward's Island, N. Y., with a capacity of 180,000,000 G.P.D., and Southwest Plant, Sanitary District of Chicago with a maximum capacity of 600,000,000 G.P.D.

Many features of the Link-Belt STRAIGHTLINE Collector are patented. Send for Book No. 1742.

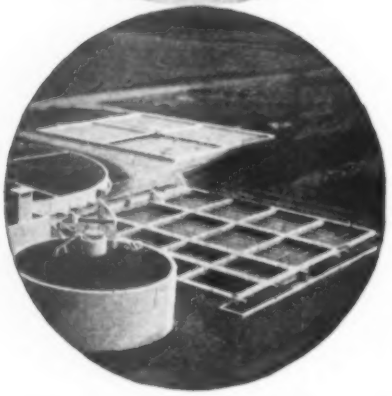
CIRCULINE COLLECTORS

Link-Belt CIRCULINE Collectors for the removal of sludge from round tanks consist of a flight conveyor suspended from a bridge, one end of which is pivoted at the center and the other end is mounted on standard rubber-tired wheels which travel around at circumference of the tank. Features are: positive, slow, uniform speed; positive sludge removal and excellent distribution of flow throughout the tank; improved automatic scum collecting screw conveyor and scum receiving hopper as standard equipment. Made in two standard sizes — Type "B" for Tanks up to 55′ dia.; Type "A" for larger sizes up to 200′ dia. Send for Book No. 1982.

STRAIGHTLINE MIXERS

Link-Belt STRAIGHTLINE Mixers of the vertical or horizontal type have proved their value in reducing chemical costs and promoting efficient flocculation in water and sewage treatment plants. They consist of a shaft to which is fastened arms which carry either wood or steel paddles that can be pivoted so that the flights can be adjusted to obtain the exact degree of uniform agitation. The maximum circumferential speed of the mixers for flocculation tanks is 1.8 f.p.s., and the minimum speed is about half of that. A gradual decrease in speed of the units is desirable for efficient flocculation.

Send for Book No. 2042.



BIO-FILTRATION System for Treating Sewage

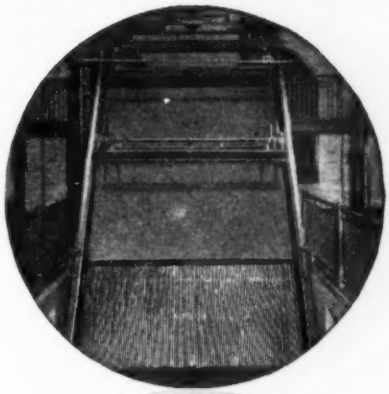
Bio-Filtration Sewage Treatment System with Link-Belt STRAIGHTLINE and CIRCULINE Collectors brings new advantages. The system consists of high rate shallow filter beds and recirculation of the effluent from the filter beds to the primary tanks. Features are great flexibility, high rate of B.O.D. loading and the ability of such a plant to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. A large number of installations of this type are now in operation. Send for Folder No. 1881.

Treatment Plans with LINK-BELT

STRAIGHTLINE BAR SCREENS

Link-Belt STRAIGHTLINE Mechanically Cleaned Bar Screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants.

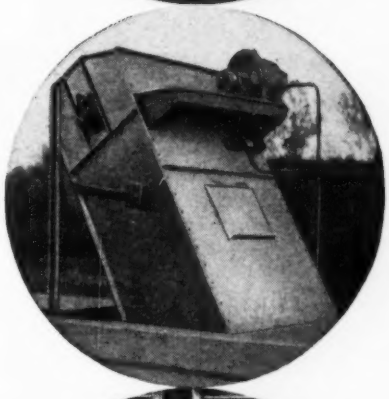
Send for Booklet No. 1587



TRITOR SCREENS

The Link-Belt Tritor Screen is a combination mechanically cleaned screen and grit chamber. It is especially designed for medium and small size plants. Its main elements are a hopper, a bar screen, and a bucket elevator for removing the solids accumulated on the screen and the grit from hopper. The buckets are perforated for drainage and have rake teeth for cleaning the screen. Adjustable baffles regulate velocity of flow through the hopper.

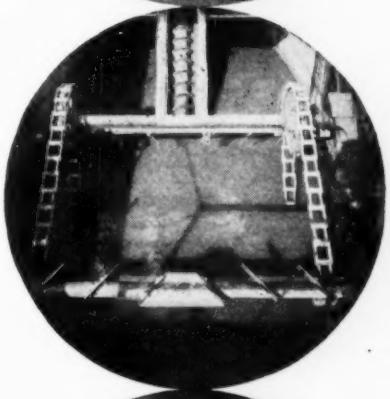
Send for Booklet No. 1587.



STRAIGHTLINE GRIT COLLECTORS and WASHERS

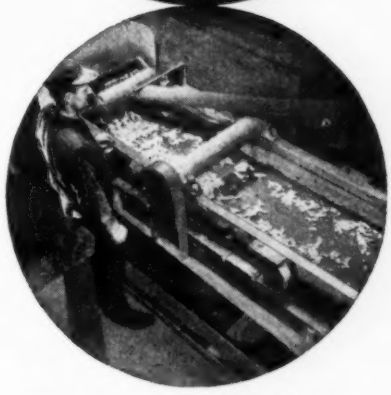
The Link-Belt STRAIGHTLINE Grit Collector and Washer collects the settled grit and frees it from putrescible organic matter. This unit consists of a scraper type collector with pitched flights, and an inclined washing and dewatering screw to which the collector conveys the grit. The grit is discharged washed and dewatered above the water level by the screw.

Send for Book No. 1942.



INDUSTRIAL WASTE SCREENS

The Link-Belt Industrial Waste Screen is an efficient and economical unit for the removal of objectionable suspended solids from industrial waste before the water is discharged into sewers or streams. The screenings come off the machine with a minimum of moisture. Units are available in several sizes and with coarse or fine screen medium. Wastes from canneries, textile mills, steel mills, etc., are handled successfully by these screens. Send for Book No. 1977. We also manufacture rotary screens for similar service.



OTHER LINK-BELT EQUIPMENT INCLUDES: STRAIGHTLINE Scum Breakers for Digestion Tanks; Air Diffuser Units for degreasing, aeration and mixing of liquids; Non-Clogging Spray Nozzles; Traveling Water Intake Screens; Rotary Screens; Roto-Louvre Heat Dryers; Coal and Ashes Handling Machinery; Car Spotters and Haulage Systems; Shovels-Cranes-Draglines—Crawler and Wheel Mounted; and a complete line of Elevating, Conveying and Power Transmission Machinery. Catalogs sent on Request.

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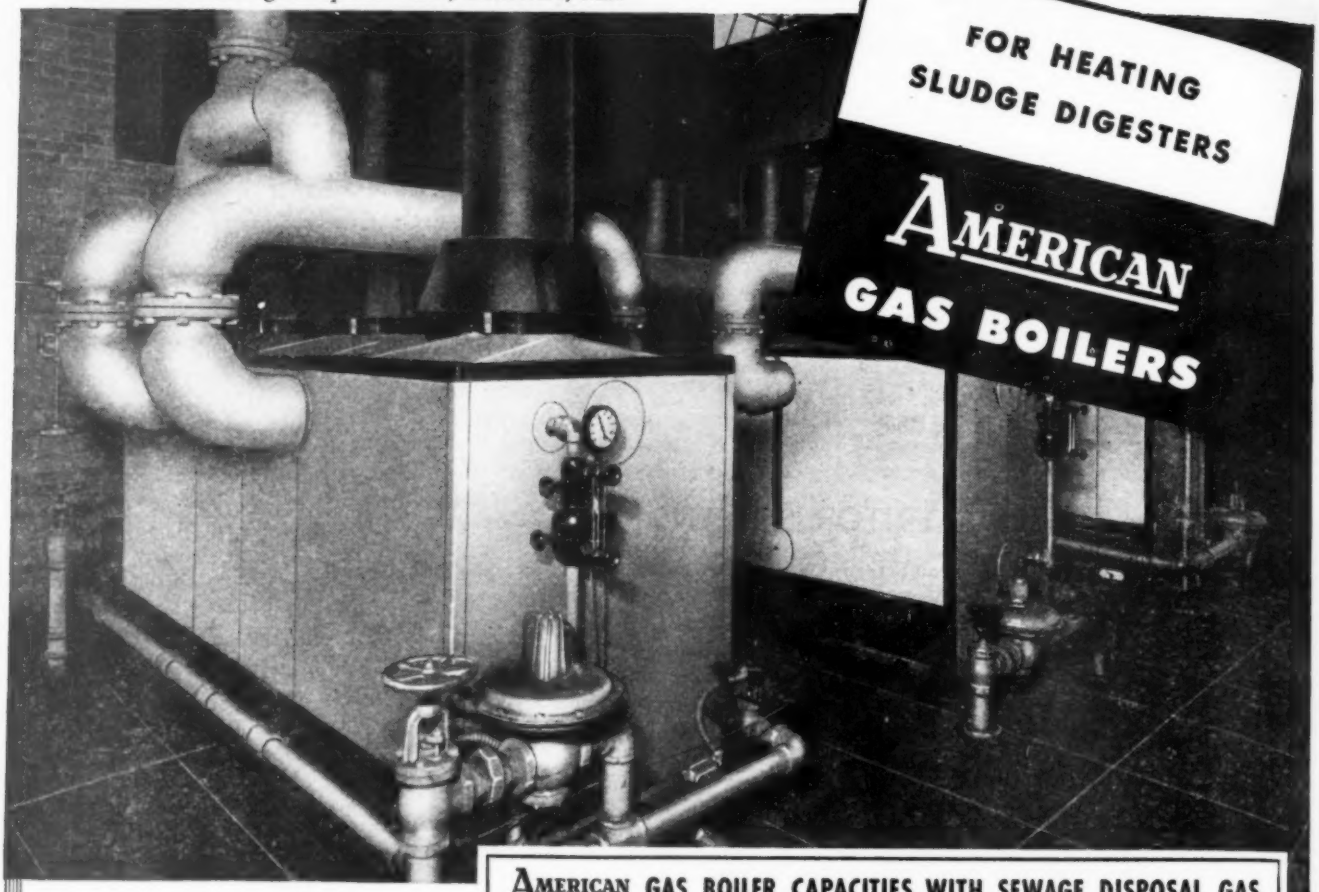
3 No. 4-GS-25 American Gas Boilers installed in the Back River Sewage Disposal Plant, Baltimore, Md.



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AMERICAN GAS BOILERS

Make the experience of others your guide to trouble-free heating

To heat sludge digesters, sewage plants from coast to coast rely on American Gas Boilers. Let the hundreds in service guide your own selection.

These boilers are engineered for dependable operation and are especially adapted for burning sewage gas. They are completely automatic, one valve controlling water temperature to any predetermined degree. Pintype sections afford the most effective type of cast iron heat-absorbing surface. Controls are available to accommodate any desired system of gas, temperature, or pressure regulation. A wide range of sizes meets all requirements. For complete detailed information, write American Radiator & Standard Sanitary Corporation, P. O. Box 1226, Pittsburgh 30, Pa.

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AMERICAN GAS BOILER CAPACITIES WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU. per Hour	Cu.Ft. 700 BTU. Sludge Gas	Over-all Hgt xx	Floor Space	
								Width Front	Depth
.....	1-GA-4E	31,500	....	210	39,350	56	40½"	16"	20½"
.....	1-GA-5E	42,000	....	280	52,500	75	40½	16	23½
.....	1-GA-6E	52,500	....	350	65,600	94	40½	16	26½
.....	2-GA-4E	63,000	....	420	78,750	113	50½	16	23¼
.....	2-GA-5E	84,000	....	560	105,000	150	50½	16	26¼
.....	2-GA-6E	105,000	....	700	131,200	188	50½	16	29¼
.....	2-GA-7E	126,000	....	840	157,500	225	50½	16	32¼
.....	4-GA-8E	147,000	....	980	183,750	263	54	16	37¼
.....	4-GA-9E	168,000	....	1120	210,000	300	54½	16	40¼
.....	4-GA-11E	210,000	....	1400	262,500	375	54½	16	46¼
.....	4-GA-13E	252,000	....	1680	315,000	450	56	16	52¼
0-GS-4E	.....	61,200	255	.....	76,600	109	52¼	16	33¾
0-GS-5E	.....	81,600	340	.....	102,000	146	53	16	37¾
0-GS-6E	.....	102,000	425	.....	127,500	182	52¼	16	41¾
1-GS-4	1-GW-4	146,000	610	980	182,500	261	54½	35	33¾
1-GS-5	1-GW-5	186,000	775	1240	232,500	332	56¾	39	33¾
1-GS-6	1-GW-6	225,000	940	1500	281,500	402	56½	43	33¾
1-GS-7	1-GW-7	265,000	1105	1770	331,000	473	57	47	33¾
1-GS-8	1-GW-8	305,000	1270	2030	381,000	545	59¼	51	33¾
1-GS-9	1-GW-9	345,000	1435	2300	431,000	616	58½	55	33¾
1-GS-10	1-GW-10	384,000	1600	2560	480,000	686	59¼	59	33¾
1-GS-11	1-GW-11	424,000	1765	2820	530,000	757	59	63	33¾
4-GS-6	4-GW-6	480,000	2000	3200	600,000	857	74	53	52
4-GS-7	4-GW-7	576,000	2400	3840	722,000	1030	75	58	52
4-GS-8	4-GW-8	672,000	2800	4480	840,000	1200	77	62	52
4-GS-9	4-GW-9	768,000	3200	5120	960,000	1372	77¾	66	52
4-GS-10	4-GW-10	864,000	3600	5760	1,079,000	1543	79½	70	52
4-GS-11	4-GW-11	960,000	4000	6400	1,200,000	1715	80	74	52
4-GS-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	75	85	64
4-GS-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	77	93	64
4-GS-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	77¾	103	64
4-GS-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	79½	107	64
4-GS-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	80	110	64
4-GS-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	77	136	64
4-GS-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	77¾	148	64
4-GS-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	79½	160	64
4-GS-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	80	172	64
4-GS-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	77¾	186	64
4-GS-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	79½	202	64
4-GS-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	80	218	64

xx *To top of Draft Hood*

GAS HAZARDS*

Methods of Reducing Such at Sewage Treatment Plants

PART I

OPERATION AND MAINTENANCE

Instructions to Operators and Superintendents

Sewers.

a. Solids should never be allowed to accumulate in sewers to give off gas during their decomposition. Frequent inspection, by means of gas detectors, are suggested to determine if explosive or toxic gases are present. Periodic flushing of sewers is also suggested, particularly in sections at flat grade or near dead ends.

b. Inflammable or volatile liquids, such as petroleum products, oil or cleaning solutions, should not be permitted to gain access to the sewers. Garages, dry cleaning establishments, or any building handling volatile or inflammable liquids should be equipped with traps on their sewer connections to intercept such liquids at their source. Frequent inspections of establishments using such products are required to eliminate this all too frequent source of danger. Persuasive letters or the enforcement of a local ordinance or fire code may be used to enforce their exclusion.

c. As much ventilation as possible should be provided. Any complaint relative to odors from sewers must be given careful consideration, the odor traced to its source and eliminated rather than sealing manholes and thus permitting what could easily be an explosive or toxic gas to increase in concentration.

Plant Odors or Sanitation.

a. All pockets which collect solids should be eliminated and ventilation ducts should be maintained at all points where gas might accumulate. The vapors caused by gasoline and similar products are heavy and should be removed from low points of enclosures, preferably at the point of entrance to the plant, while the so-called sewer gas is lighter than air and must be removed at the top of enclosures (incoming sewers must be trapped to provide positive ventilation). Where provided ventilating systems should be used at all times. Where no ducts or fans are provided their installation should be urged. A mixture of air and inflammable gases in ducts is liable to be explosive, therefore, the blower must be of the non-sparking type suitable for such work and the motor must be as approved by the National Board of Fire Underwriters for hazardous atmospheres.

b. Screen chambers, weir chambers, channels and all pockets where sludge or floating solids may accumulate should be flushed clean at least one daily; more often in summer. Any sludge or supernatant liquor spilled during sampling or drawing should not be allowed to stand to give off dangerous gases or odors. Water or clarified effluent under considerable pressure should be available for these purposes.

c. Scum and screenings should be removed daily.

d. Wet wells at treatment plants or outlying pumping stations should be maintained clean enough, at all times to prevent gas formation.

(The above applies to the removal of sources of gas formation which will, by their toxic effect, lower the vitality of the plant personnel if not present in sufficient concentration to become lethal or explosive. The gases present at sewage treatment plants do not always give warning of their presence by the sense of smell.)

Plant Operation.

a. Care must be exercised in drawing sludge or supernatant liquor from digestion tanks with fixed covers. At no time should the liquid level in this type of digester be lowered to a point where the gas is no longer under pressure. The installation and use of gas storage devices cannot be too strongly recommended to compensate for the lowering of liquid level in digesters. Where gas storage units are provided, no attempt should be made to lower digestion tank levels unless sufficient gas is stored to compensate for such lowering of liquid levels; an alarm on gas holders could be installed to warn when the volume of gas is lowered to a predetermined level. Gas holders or floating covers should never be permitted to come to rest (grounded) unless they are to be taken out of service, in which event they should be purged with an inert gas under competent supervision. (Information relative to purging may usually be obtained from local gas engineers.)

b. Sludge levels should be held low enough below gas domes or outlet pipes to prevent the entrance of solids to gas lines. A float operated pump cut-off switch, alarm, or overflows are recommended to keep the scum level(s) below a predetermined point.

c. A daily examination should be made of the liquid levels of all seals. Any liquid displaced or lost by evaporation should be immediately replaced. The use of a non-evaporating anti-freeze solution is recommended.

d. It is suggested that a chart be set up requiring the daily or hourly notation by the operator or assistants of any data pertaining to gas pressures, sludge levels, liquid or sludge to and from the digestors, gas production, attention to seals or any other data relative to the safe handling of sludge gas. A monthly check of conditions of safety and first aid equipment is recommended.

Safety Measures.

a. All gas handling equipment should be maintained gas tight. Joints should be periodically tested by a soap test for leaks.

b. "U" traps, drips or any outlets into enclosed space should not be permitted. Any such outlets found should be eliminated or, if necessary, vented out-of-doors. Under no condition should they be vented to sewers.

c. All enclosed spaces should be properly ventilated (forced ventilation preferred) so that, should leaks in gas handling equipment develop, no toxic or explosive mixture will be built up. Confined spaces frequently used should be constantly ventilated and less frequented enclosures thoroughly ventilated before use.

d. As a precautionary measure, but far from foolproof where explosion hazards exist, all possible sources of ignition should be eliminated—such as:

Flames: Open lights. matches, cigar lighters, fires, blow torches.
Sparks: From tools, lightning, static, electric shorts, motors.
Heated Materials: Heated metals, hot cinders, glowing tobacco.

The judicious use of "No Smoking" signs is recommended where explosion hazards exist. Too liberal use of these warnings tends to minimize their effectiveness. The use of electrical equipment designed for hazardous atmospheres and spark-proof tools is recommended.

e. Electric motors should be permanently and effectively grounded.

f. It is strongly recommended that whenever it becomes necessary to enter any enclosure—such as a digestion tank—in which an oxygen deficiency or an explosive gas or toxic gas is liable to be found, the following precautions be observed: Completely drain any residue of sludge and purge the tank with water and/or an inert gas. Do this with a minimum of manhole disturbance to prevent possible ignition by sparks. Thoroughly ventilate (force draft if possible, never suction unless by means of spark-proof blowers and motors). A workman (or workmen) must never attempt, or be assigned, to enter such an enclosure unless they are equipped with a gas mask of the hose or oxygen helmet type (never canister) and a safety harness (not simply a rope tied around his body) to which is attached a rope strong enough to support his weight, tied at the top and attended by sufficient man power to pull him out if necessary. Maintain communication between the men in the enclosure and those on top. Rubbers or boots should be worn and a great deal of caution observed to prevent sparks from tools or static electricity such as rubbing or striking metal buttons. Masks and safety harnesses must be kept dry and their condition checked frequently. Never attempt to use this equipment without thoroughly testing. All plant personnel should be thoroughly familiar with their use. Only lights that are approved by the National Board of Fire Underwriters for hazardous atmospheres must be used. These same precautions should be observed with the necessary modifications when entering or working in sewer lines. Air and digestion gas must never be mixed in digesters, piping or any gas handling equipment. When digestors or equipment are placed in service or taken out of service, the entire system must be purged with water, an inert gas, or a combination of the two.

g. Gas and oil burners should be installed and used under local

*From the 1940 report of the Committee on Hazards of the N. J. Sewage Works Association.

ordinances or codes and the National Board of Fire Underwriters codes relating to such equipment.

h. A supply of chlorine should be maintained in any process building sufficient for normal demands only. The main supply should be stored in a detached non-combustible building or, if in a room attached to the main building, it shall be of fire-proof construction and separated from the main part of the building by a fire-proof door constructed under the regulations of the National Board of Fire Underwriters. The room or building should be used for no other purpose and should be kept locked at all times to prevent the entrance of unauthorized persons.

i. Two yellow canister masks should be provided for use in chlorinous atmospheres. They should be kept in a dry place which is handy to chlorine storage or use, yet not liable to exposure to chlorine fumes in event of leaks. Every man at the plant should be thoroughly familiar with their use.

Safety Equipment.

The following equipment is recommended for all sewage treatment plants at which sludge gas is collected or burned:

a. A hose mask or oxygen helmet, a safety harness [and two yellow canister masks for use in chlorine gas if included in treatment.)

b. Fire Extinguisher. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Sewage treatment plants should be provided with a suitable instrument for detecting explosive gases and for detecting H_2S. Illuminating gas in sewers may be detected by means of relatively cheap ampoules which indicate the presence of carbon monoxide (CO). A Wolf safety lamp, explosion meter, Orsat apparatuses, or similar equipment are required to test for explosive mixtures Hydrogen sulphide (H_2S) may be detected by several commercial apparatuses or by a 5% solution of lead acetate.

d. First aid equipment. Personnel employed at sewage treatment plants should have a knowledge of artificial respiration, knowledge of the location of the nearest safety team equipped with an inhalator, and list of doctors and other aids to be called in emergency. (The local gas or electric company usually maintains a safety squad equipped with an inhalator.)

It is suggested that operators and their *assistants* attend first aid meetings and familiarize themselves with first aid and artificial respiration methods. It is suggested that night operators or single operators be required to call the local police station or some other agency hourly and that failure to do this will result in a check-up of the operator's condition by the police. An accident may thus be prevented or a life saved.

e. Manometers or other pressure indicating devices, located at points visible from valves or other controls used to change the levels of digestion tanks which will indicate gas pressures within the digester and at all other seals. Manometers should be installed in such a manner that the liquid contained therein cannot be blown out to permit the escape of gas into any enclosure.

f. A telephone for use in summoning aid in case of fire, explosion or asphyxiation.

PART II

PLANT DESIGN, PIPING, EQUIPMENT

Sludge Digestion Tanks.

1. *Tanks:*

a. Covered separate sludge digestion tanks shall be provided with means to maintain gas under pressure at all times to allow for reasonable operating fluctuations of liquid or scum levels. Fluctuations in liquid or scum levels will be considered in relation to the volume and moisture content of raw sludge. For domestic sewage, this volume should be from a minimum .3 cubic ft. per capita for plain sedimentation to a minimum of .5 cu. ft. per capita for activated sludge.

b. Covered separate sludge digestion tanks shall be constructed or treated so that they are impervious to gas, and no buildings shall be erected over them.

c. All openings in tanks with fixed covers shall be sealed gas tight. Curtain walls or sampling pipes shall extend at least 6 in. below reasonable operating levels as required in section 1 (a).

d. All closed digestion tanks shall be provided with means for safe disposal of gas as further provided in these recommendations.

2. a. Where gas is collected, domes or similar devices shall be provided at the high point(s) of the digester cover.

b. A safety pressure release with adequate flame protection shall be provided for each collecting dome or floating cover. This device shall be installed to release excess pressure directly from the digester. It shall be designed to operate at a pressure of at least 2 in. of water above maximum operating pressure.

Pipe Lines.

1. *Piping:*

a. Pipe lines to be used for the collection and transmission of digster gas shall be of gas tight construction and shall be pitched with a grade of not less than ½ in. in 15 ft. with drips provided at low points. Consideration should be given to the insulation of exposed lines to prevent freezing of moisture. All piping shall meet the Good Practice Requirements of the National Board of Fire Underwriters.

b. No siphon or "U" taps shall be installed on drips and all automatic drip discharges shall be to a point outside any enclosure. In no case shall this be to any sewer or pipe line.

c. Minimum pipe sizes for gas lines shall be 2½ in. Non-insulated lines exposed to freezing temperature should be double the above capacity. It is suggested that all gas piping be three times its designed capacity.

d. Pipe lines to gas engines shall be suitably protected against flame propagation and excess pressure. All such lines should be independent of all other piping. Sizes and appurtenances shall be determined by the specific engine requirements.

e. Valved by-passes should be provided for all meters.

f. Means should be provided to permit purging all gas handling equipment of sludge gas or air.

g. Means shall be provided to prevent the accumulation of sludge or supernatant liquor in sampling sinks or channels within enclosures.

2. *Valves:*

a. Shut-off valves should be provided for the sub-collection lines for each tank and in the main line before and after the pressure relief and flame traps.

b. Pipe lines or valves shall not be installed permitting the by-passing of flame traps or pressure reliefs.

Equipment.

1. *Pressure Regulation:*

a. Means shall be provided to maintain a minimum working pressure of 2 in. of water in gas piping at the point[s] of consumption.

b. Equipment or devices shall be provided which will confine the fluctuations in working pressure within the gas piping system to a definite limit or range (see also Waste Gas Disposal).

c. Any equipment or device designed for the collection or storage of gas in which excessive pressure may be built up when the flow of gas therefrom is stopped shall be equipped with a device that will permit the escape of gas. It shall discharge at a minimum of 2 in. water pressure over the pressure required in the unit to maintain the designed maximum working pressure within the gas system. Such gas discharges shall not be to any enclosure.

2. *Flame Trap(s) or Arrestors(s):*

a. A flame trap shall be provided close to the service end of all supply pipes, with no connection to a gas consuming unit between the flame trap and source of supply not protected by another flame trap.

b. Flame trap(s) shall be suitably protected from the elements.

c. Where gas engines are to be used, separate flame traps shall be installed on the line (see "Pipe Lines" 1 [d).

3. *pressure Relief(s):*

a. An automatic pressure relief shall be provided suitably protected from the elements.

b. Where gas engines are to be usd, a separate pressure relief shall be installed, of the dry seal type (see "Pipe lines" 1 (d).

4. *Seals and Vents:*

a. Equipment requiring liquid seals shall be provided with indicators clearly showing the liquid levels to be maintained and means shall be provided to introduce an additional supply of sealing liquid.

b. Liquid seals on equipment in locations exposed to freezing temperatures shall be anti-freeze solution.

c. Vents or drip discharges shall be piped to the outside and not to any sewer or pipe line.

5. *Waste Gas Disposal:*

a. A waste gas line shall be provided which will discharge into the atmosphere at a point outside the building at a height sufficiently above ground or surrounding structures to insure proper and adequate dilution, or to a protected burner.

b. The excess gas line shall be free of valves or other possible obstructions.

6. *Waste Gas Burners:*

a. Waste gas burners shall be designed and installed so as to maintain a flame in high winds or rain and shall be provided with a flame trap and a pilot from the outlet side of the main flame trap or an individual flame trap.

b. Waste gas burners shall not be placed nearer than forty (40) ft. from digestion tanks or twenty [20) ft. from any building. They may, however, be placed at least five (5) ft. above flat roofs or two (2) ft. above ridges of gable roofs of buildings provided they are at least fifteen (15) ft. from any higher story or any adjacent building and the roof is of fire-proof construction.

7. *Gas Meters:*

The installation of gas meters is recommended to measure the production and consumption of gas.

8. *Pressure Gages:*

a. A gage, or gages, to show in inches of water (or equivalent) the gas pressure in the digestion tank shall be provided and located so as to be visible at the points of control for the withdrawal of sludge and supernatant liquor.

b. Pressure gages in the line(s) before and after the flame traps and at points of gas utilization are desirable.

c. Manometers shall be designed to prevent escape of gas into any enclosure caused by a blow out of liquid.

9. *Boilers:*

a. Gas and oil burners should be installed and used under local ordinances or codes and the National Boar of Fire Underwriters codes relating to such equipment.

b. Flues from gas heaters shall be separate from building heating plant shimney and shall be carried above roof a minimum distance of three [3) ft. above flat roofs or two (2) ft. above ridge of gable roofs, or if near chimneys an additional height of at least eighteen (18) in. above adjacent chimneys.

c. Siphonage or other type of ventilators on top of flues that will prevent backdraft are recommended.

10. *Gas Holders:*

a. Where gas holders are installed to compensate for differences in liquid or scum elvations in digestion tanks, they should have capacities as required under "Sludge Digestion Tanks 1 (a)." They shall be connected so that any lowering of liquid level in the digester is compensated for by a flow of gas from the holder to the digester. Alarms or cut-off switches are recommended to maintain the volume of gas in the holder above a predetermined minimum.

b. The capacities of gas holders to be used in conection with gas engines shall be considered in relation to the engine requirements.

c. Gas holders of the high pressure type shall include a balancing suction tank and automatic regulators to pump controls.

11. *Ventilation:*

a. Forced draft ventilation shall be provided with outlets at or near the sewage level in enclosed screen chambers, covered sedimentation tanks, and at all points where either heavy or light gas may accumulate. Ventilation by suction is recommended.

b. Ventilating fans shall be of the non-sparking type suitable for hazardous atmospheres. Motors shall be so mounted that no contact is made with the air in ducts or blowers and shall be constructed as approved by the National Board of Fire Underwriters for hazardous atmospheres. Electric motors shall be permanently and effectively grounded.

12. *Housing of Equipment:*

a. Where installed in buildings, heating equipment, flame traps, pressure reliefs, gas meters, etc., shall be located in a separate building or room. The room shall be cut off from the rest of the building by fire-proof walls as approved by the National Board of Fire Underwriters. The entrance to the room or building shall be from the outside and through a door designed to swing outward.

b. The floor of the building or room housing such equipment shall not be located below the ground surface and, if over or under other parts of a building, shall be of gas-proof construction.

c. The room or building shall be ventilated at both the floor and ceiling.

d. The walls of the building or room shall have liberal glass area consisting of thin glass sash. Where, because of exposure, it is necessary to use wired glass, sash shall be so hung that they will readily swing out in case of an explosion. Such sash shall not be secured.

e. All electric wiring, including lights and switches, shall be as approved by the National Board of Fire Underwriters.

f. The use of individual gas heaters is not recommended to burn sludge digestion tank gas.

13. *Safety Equipment:*

a. A hose mask or oxygen helmet and safety harness shall be provided.

b. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Gas detectors for inflammable or toxic gases are recommended.

d. A telephone is recommended.

14. *Chlorine:*

a. A separate building or room of fire-proof construction as approved by the regulations of the National Board of Fire Underwriters shall be provided for chlorine storage. It shall be designed solely for chlorine storage, adequately ventilated and its door provided with a lock.

b. Gas masks for use in chlorinous atmospheres are recommended.

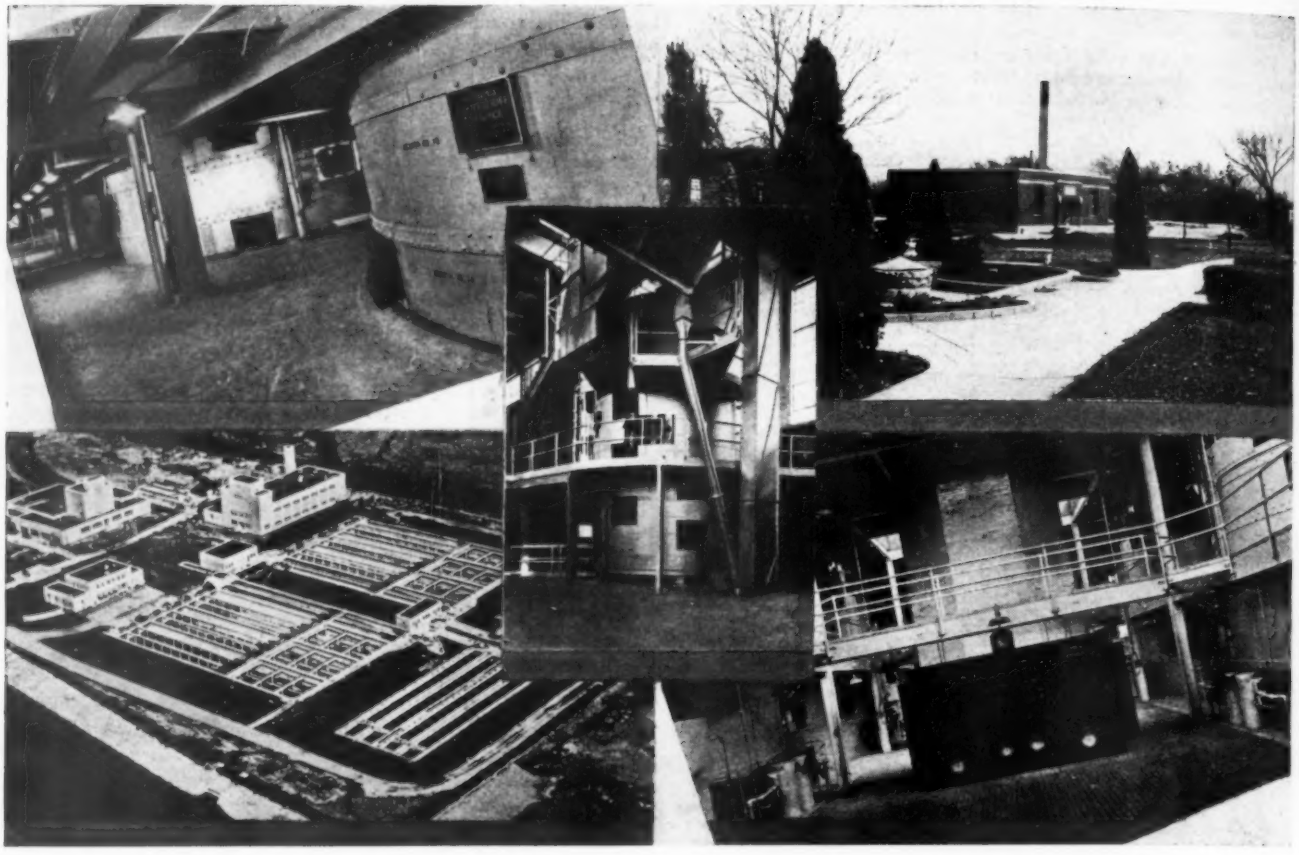
Edward F. Shissler, *Chairman*, Leigh Morril, *Secretary*
R. M. Cadman, I. R. Riker.

Limits of Flammability of Gas-Air Mixtures*

THE above table gives the approximate limits of flammability of gasses when admixed with air at ordinary temperatures and approximately atmospheric pressure. The list includes those gases found in sewers and at sewage treatment plants. The figures represent % by volume of the respetcive gasses in the air-gas mixture. The "Lower Limit" is that below which explosions *will not* occur; the "Upper Limit" is that below which flame propogation *will* be experienced, if not explosion; and above which the ratio of oxygen to gas is not sufficient to support burning or flame propogation in a closed tube or vessel.

	Lower Limit By Volume	Higher Limit By Volume
Ammonia	14.8	79.0
Methane (static)	4.3	14.0
Methane (turbulent)	5.0	15.0
Hydrogen	4.1	74 0
Hydrogen Sulphide	4.3	46.0
Carbon Monoxide	12.5	74.0
Water Gas	9.0	55.0
Natural Gas	4.8	13.5
Illuminating Gas	5.3	31.0
Blast Furnace Gas	35-37	65.0
Methane and Hydrogen Sulphine	4.1	71.5
Methane and Nitrogen	5.8	12.8

*Courtesy of The Vapor Recovery Systems Co.



FACTS on Sludge Incineration for every community planning modern sewage disposal

Nichols Herreshoff Incinerators are successfully incinerating sludge produced by each of the basic methods of sewage treatment: Primary, Chemical, Bio-chemical, Activated—either in raw or digested condition.

Nichols Herreshoff Sludge Incinerator installations range in size from 4 tons of cake a day to 1,200 tons of cake a day.

Liquid sludge consisting of 85-90% water is being successfully incinerated. Where this type of plant can be installed, the saving in design, construction, chemicals, reduced maintenance and labor, make it a very worthwhile undertaking.

Nichols Sludge Incinerators are meeting the needs of large and small communities for a sanitary, healthful and efficient means of disposing of sewage and industrial wastes. The installations are characterized by their simplicity of design, flexibility of operation and dependable performance.

Literature describing Nichols Herreshoff Incinerators is available and will be forwarded upon request.

NERCO

NICHOLS ENGINEERING & RESEARCH CORPORATION

60 WALL TOWER, NEW YORK 5, N. Y. UNIVERSITY TOWER BLDG., MONTREAL, P. Q.

CARTER

MECHANICAL PROCESSING EQUIPMENT

for

Water Purification and Sewage Treatment

Present day demands for improved machines and equipment are bringing about vast changes in the design, manufacture and maintenance of all mechanical apparatus. This is especially true in the art of water, sewage and industrial waste treatment.

To meet these demands manufacturers must religiously follow an extensive research program, to develop new equipment, and assay for a better product thru improved design and fabrication methods!

It is here in this research phase of manufacturing, that the developments of tomorrow take shape . . . from the embryonic idea, to the perfected method or machine. It is here that CARTER engineers carry on a continuous program to further the advance of new and improved equipment.

In an abbreviated form on the pages that follow, we present typical CARTER mechanisms that our engineers have developed for application in the water, sewage and industrial waste field. Full and specific information will be gladly furnished on request . . . no obligation, of course.

RALPH B. CARTER COMPANY

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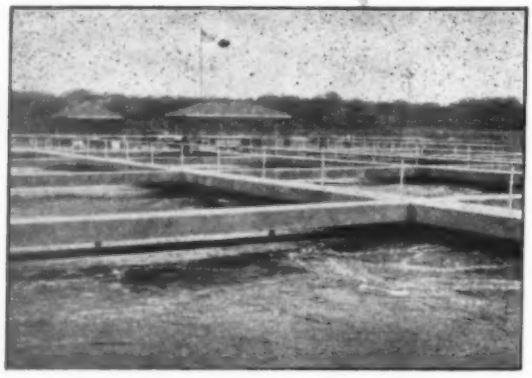
CARTER *Mechanical Mixing*



Mechanical mixing . . . one phase of water or sewage treating on which most engineers are in complete agreement. They know the added efficiency, the substantial dollar saving and the improved chemical mixing adds up to an effectual increase in overall plant results.

For your next design may we recommend CARTER mechanisms for your serious consideration. These carefully engineered, ruggedly constructed units are guaranteed to give you 100% satisfaction on your most difficult assignment.

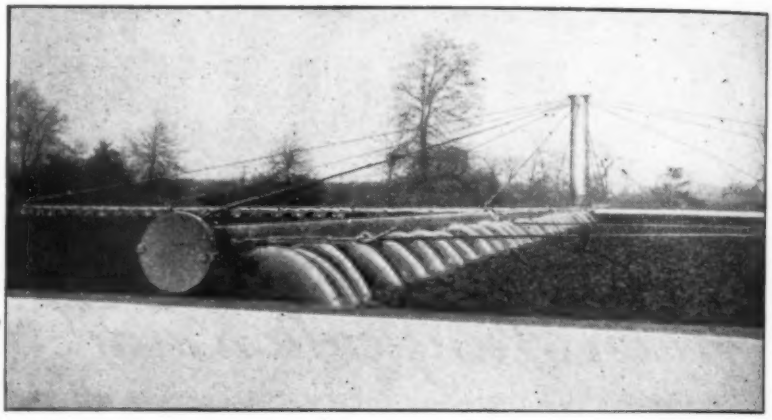
★*Write for Bulletin No. 4501*

CARTER *Rotary Distributors*

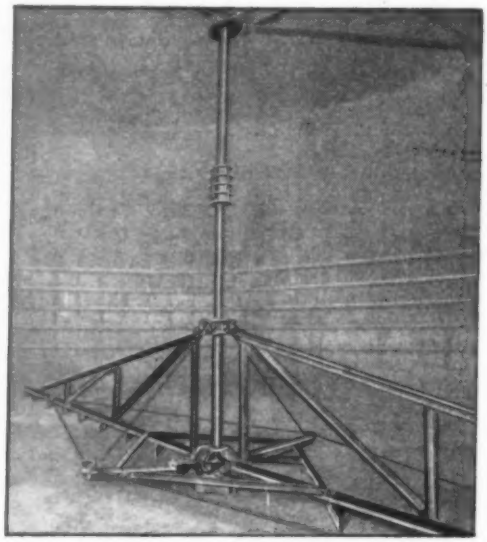
Typical of the major items manufactured by CARTER for waste treatment, the reaction type rotary distributing unit reflects sound engineering in both its mechanical development as well as its actual processing ability.

The perfection of the CARTER leveling flange which permits column realignment due to faulty sub-soil, and the introduction of an entirely new principle in the *Deflec-ta-spray* nozzle, are but two of its many features.

★*Write for Bulletin No. 4401*



CARTER *Digesters*



Concentration and digestion of both primary and secondary solids is most effective, if this settled material is stored in a closed tank, temperature controlled, and *gently stirred during this storage period.*

The stirring action is of primary importance in this process because with it, all surface scum accumulations are continuously broken up, the ripe digested sludge is positively moved from the tank periphery to the central sludge pocket, and the production of sewage gas is facilitated.

The CARTER mechanism that has been developed for this service is a ruggedly constructed unit, that has been designed to meet the maximum demands of this phase of sewage treatment.

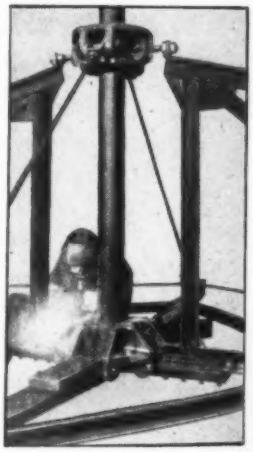


Illustration above shows "custom" fabrication of sludge scraper mechanism of 60' diameter fixed roof tank. Note the heavy duty features of these members.

★*Write for Bulletin No. 4311*

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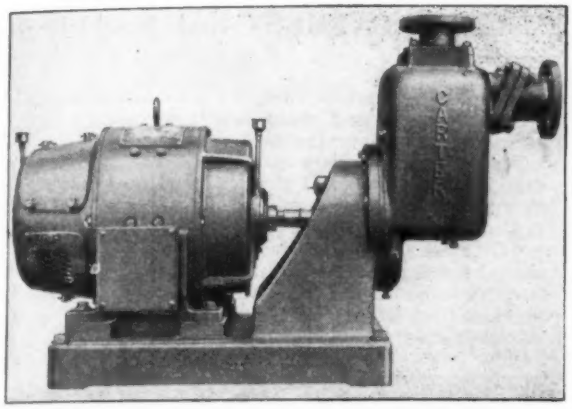
CARTER *Contractor's Pumps*



Used extensively in the industrial field, both the long coupled or the close coupled type illustrated, have proven reliably efficient and trouble free on water or sewage applications demanding a centrifugal pump with automatic self-priming ability.

New construction features include a co-axial type volute with but one moving part. With this new development, capacities of from very few, to many hundreds of gallons of liquid are obtainable with a minimum of maintenance costs.

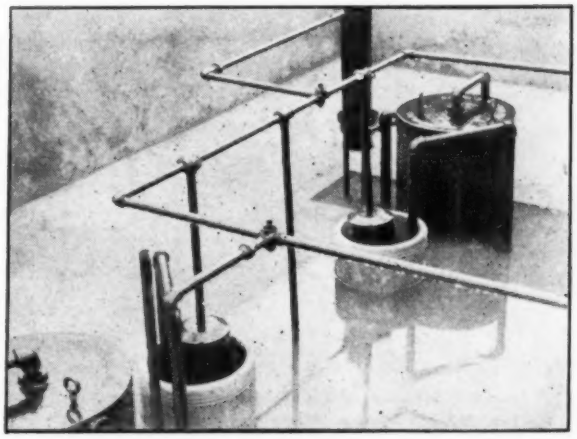
★ *Write for Bulletin No. 4310*

CARTER *Centrifugal Pumps*

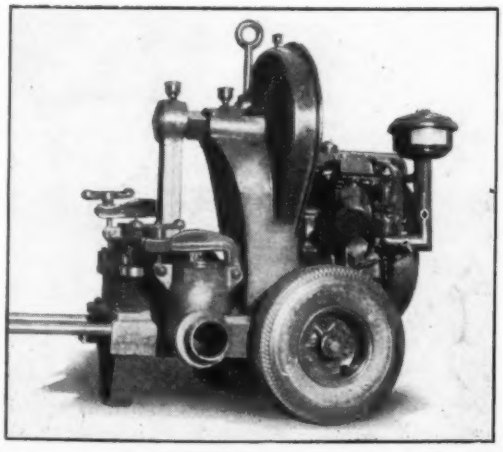
Where a high degree of secondary treatment is required, analysis has shown the sand filter bed method both economical and efficient. This is especially true of installations employing automatic alternating siphons. These installations show *final results equal to, and in many cases superior to, other methods regardless of cost.*

If you plan using the sand filter bed method of secondary treatment, we recommend for your serious consideration the CARTER fully automatic siphon, designed for trouble-free operation, and guaranteed to give quick, uniform alternate cycle distribution. Standard sizes range from 6" to 24" in the single, double or plural type and cover a capacity range of from 280 to 10,000 GPM.

★ *Write for Bulletin No. 4312*



CARTER *Alternating Siphons*



Portable dewatering equipment . . . a *must* on every plant operator's equipment list, demands a versatile unit of sturdy, rugged construction, that will give hour after hour of continuous duty operation in any emergency.

The dependable CARTER Model 30B single diaphragm unit illustrated at left has earned such a reputation on general utility service. For effective handling of liquids containing a high solid content, *it has no equal.* Both the single and double types are now available in 3" and 4" sizes.

★ *Write for Bulletin No. 4503*

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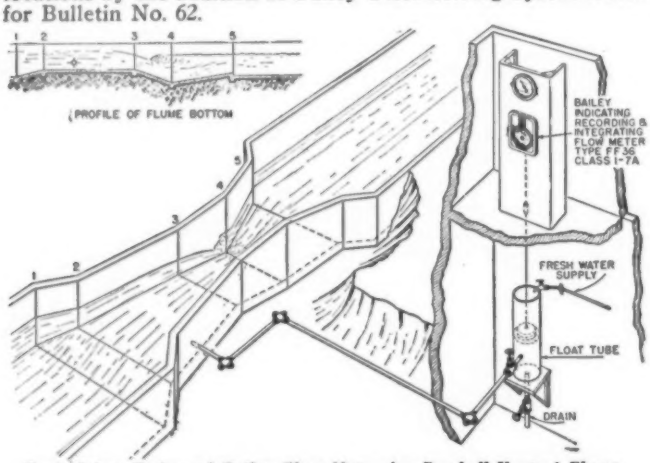
METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

Bailey Flume Meter—Simplicity of installation, low head losses and self-cleaning features of the Parshall Flume have resulted in a greatly increased use of this device for a measurement of Sewage Flow in open channels.

The Bailey Flume Meter is simple and accurate. As shown in the illustration, it consists of a single float which is connected by a flexible cable to the sturdy recording, integrating and indicating mechanism on the panel board. The panel board may be omitted if desired and the recording mechanism mounted on a wall or column. This device may be adapted to any type of open channel metering over any operating range required. Its capacity can be altered in the field by installing new gears and/or cam without disturbing any other parts of the installation.

Standard Bailey Indicating, Recording and Integrating Instruments are used, charts are 12 inches in diameter and uniformly graduated. Instruments may be placed in remote locations by the addition of Bailey Telemetering Systems. Ask for Bulletin No. 62.


PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF 36 CLASS I-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

Typical installation of Bailey Flow Meter for Parshall Venturi Flume.

Bailey Weir Meter—For measuring flow using any type of Weir notch, highly accurate results can be obtained with a Bailey Weir Meter. This meter is similar to the Bailey Flume Meter and possesses the same features of sturdiness, flexibility and accuracy. Remote transmission can be provided when desired.

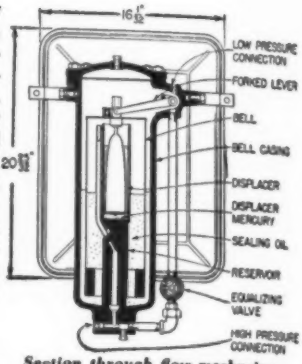
Open Float Type Meter—The Bailey Float Type Meter is especially adapted to measure the flow of sewage, sludge, dirty water or other liquids in pipe lines using a Venturi Tube, flow nozzle or eccentric orifice.

This meter is operated through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes. It is similar in external appearance to the Bailey Flume Meter.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey Register previously described. Remote recorders may be provided by Bailey Telemetering Systems which operate electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

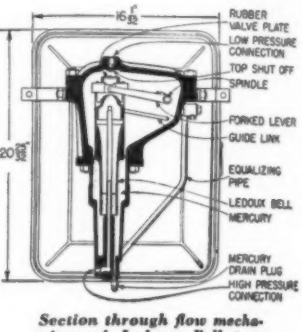
Described in bulletin No. 301-A.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 88-in. of water. *Described in bulletin No.* 301A.



Section through flow mechanism of Ledoux Bell type Register.

Remote Registers — Bailey Telemetering Systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi Tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey Gages and Registers.

Bailey control is fully automatic, dependable and exceptionally flexible.

Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

HOURLY LOAD VARIATIONS IN RELATION TO SEWAGE TREATMENT PLANT OPERATION

By ELSON T. KILLAM
Consulting Engineer, New York City

The wide variations in the hourly load arriving at sewage treatment plants, due to the combined effect of variations in sewage strength and in rate of sewage flow, have previously been discussed by the writer.[1]

Data then available were confined to two plants, both located in Georgia. Investigations recently conducted on two systems in New Jersey involving widely different conditions than those of the two systems originally described, indicate surprisingly similar load variations.

Tests of 24-hour duration with frequent flow readings and separate analysis of hourly or two-hourly samples emphasize the following conditions in these four systems:

(1) A substantial portion of the total daily load arrives at the plant in a comparatively short operating period—see curves.

(2) The hourly variations and per cent of the total daily load arriving at the plant in any given period are not markedly different regardless of whether the load be expressed in terms of flow and B.O.D. content—or, expressed in terms of flow and suspended solids content.

(3) Load variations from hour to hour are surprisingly uniform regardless of the size of the system or other factors which might normally be expected to create widely different conditions.

(4) Hourly distribution of load and variations therein have important effects on plant efficiency and on operating procedure with many types of treatment plants, particularly chemical plants. These variables emphasize the desirability of providing for flexibility in design to allow variable operation.

Studying the Load Variations

A convenient method of summarizing sewage load variations is by means of cumulative load curves. To obtain data for such a curve, samples should be collected throughout a full 24-hour period, preferably at intervals of 15 minutes or ½ hour. These samples should be proportionate to the flow and each group of samples comprising a period of one or two hours' duration should be separately analyzed. It is also essential to take flow measurements at frequent and coincident intervals. In this way the total pounds of suspended solids or B.O.D. arriving at the plant during each hour of the day, may be ascertained. Cumulative load curves may then be constructed by selecting, first,

[1] "Hourly Load variations as a Factor in Sewage Treatment Plant Operation"—WATER WORKS AND SEWERAGE; July, 1934; pp. 237-240.

TABLE NO. 1—DATA RELATIVE TO CUMULATIVE LOAD CURVES

Curve Number	Location of System	Type of District Served	Average Flow—M.G.D.	Estimated Tributary Population	Date of Test Period	Distance from Sampling Point to Most Remote Point in System—Miles	Method Flow Measurements (*)	Data Relative to Samples
"A"	DECATUR, GA. (Shoal Creek Outlet Sewer)	Strictly Residential: Separate System	0.167	2,200	4 p. m., Sat., Oct. 28 to 4 p. m., Sun., Oct. 29 1933	2.5	90 deg. V Notch Weir	(a)
"B"	RAHWAY, N. J. (Rahway Valley Joint Trunk Sewer for 7 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	1.84	23,000	3 p. m., Mon., July 23 to 3 p. m., Tues., July 24 1934	7.8	90 deg. V Notch Weir	(a)
"C"	ELIZABETH, N. J. (Elizabeth Valley Joint Trunk Sewer for 12 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	14.19	228,000	2 p. m., Thur., Aug. 2 to 2 p. m., Fri., Aug. 3, 1934	18.0	Venturi Meter	(b)
"D"	ATLANTA, GA. (Main Sewer Entering Peachtree Creek Plant)	Combined System; Residential, with some Industries and some Business Districts	15.22	110,000	8 a. m., Fri., May 3 to 8 a. m., Sat., May 4, 1933	8.0	Recording Gage at Station Rated by Current Meter	(a)

* All Flow Readings at half-hour intervals.
(a) Samples collected at half-hour intervals—each group of four composited and analyzed.
(b) Samples collected at half-hour intervals—each group of two composited and analyzed.

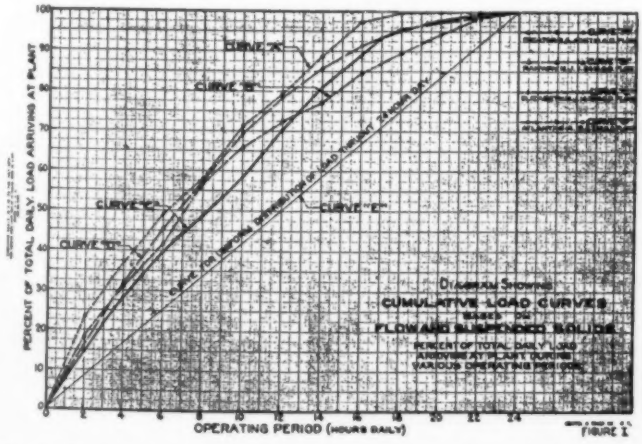


Fig. 1—Cumulative Loads, Based on Floc and Suspended Solids

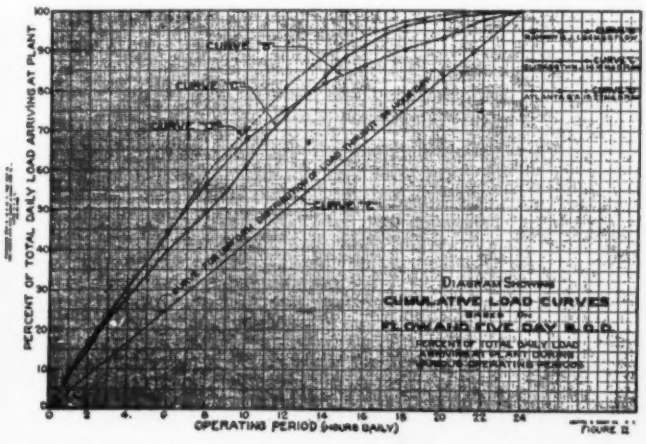


Fig. 2—Cumulative Loads Based on Flow and 5-Day Oxygen Demand

the hour at maximum load, and subsequently taking each consecutive hourly load in order of descending magnitude, and plotting of 24-hour curve. Loads expressed in terms of flow and suspended solids content, or flow and B.O.D. content, or both, may be used for the study.

Typical examples of such curves, showing data for the four system investigated, are shown in Figures 1 and 2, the former being based on load determined by suspended solids content and flow, and the later upon B.O.D. and flow.

Statistics, showing the type of system, average daily flow, tributary population, and other information, for the four systems investigated, are shown on Table 1.

Similarity in Load Variations

In view of substantial differences in type and size of the four systems referred to in Table 1, the relatively small difference in the load developed in any given number of hours in each of the systems, is of especial interest.

The Decatur (Ga.) system, for instance, involved a sewage flow of only 0.16 m.g.d. with a population of only 2,200 people in a strictly residential area, and with the most remote point in the area served only 2½ miles from the point of sampling on the trunk sewer.

On the other hand, the Elizabeth Valley System involved a total flow of 14.19 m.g.d. from a tributary system comprising several hundred miles of sewers serving 228,000 people. Remote portions of the system are at least 18 miles distant from the point at which flow measurement and samples were taken.

It might well have been expected that in such an extensive system as the latter, the variations would be smoothed out and greatly reduced in magnitude before the sampling point was reached by the passing flow. Comparison of all four curves, however, indicates that in no instance, within a fixed number of hours of operation, does the total cumulative load arriving at the plant vary by more than 13 per cent. Examination of the curves also discloses that the distribution of the load, based on suspended solids, agrees very closely with the load based on 5-day B.O.D.

What It Means

The similarity of these curves indicates that load variations in substantial proportions may be expected on every sewerage system. These variations and their effects are accordingly important in the design and operation of sewage treatment plants. in the measurement and evaluation of treatment plant efficiency; and, in the collection of river samples below sewer outlets during investigations of the pollution of receiving streams.

THE DETERMINATION OF SETTLEABLE SEWAGE SOLIDS BY WEIGHT*

By A. J. FISCHER
Development Engineer
The Dorr Co., New York City

and

GEORGE E. SYMONS
Associate Editor
Water & Sewage Works, New York City

DIFFICULTIES in the determination of suspended solids by the Gooch crucible method and possible sources of sampling errors in the method have been noted before [1, 2, 3] and a method has been proposed for the determination of settling solids by weight [2, 3, 4]. However, there appear to be several disadvantages with this method and it has not found favor in sewage laboratories. Consequently, there still is a need for a satisfactory method of determining settleable solids, particularly as they apply in flocculation studies and in the evaluation of settling tank operation.

A technique suggested by Fisher and Hillman[5] involved the use of a 10-in. by 6-in. flocculator jar filled with sewage to a depth of about 4½ inches. Approximately 250 ml. of supernatant liquor were siphoned off at a depth of 1 inch after a period of one hour of quiescent settling. Suspended solids were determined on this sample by the Gooch crucible method.

The fact that the samples were taken 1 inch below the surface (chiefly to avoid disturbance of settled solids) does not presuppose that the dispersion density of the solids remaining in the liquid is constant from top to bottom. The effect of taking off the sample at this point is merely to reduce the overflow rate used. For example, the 1 inch depth sample gives a 1 inch per hour overflow rate (15 gal. per sq. ft. per 24 hrs.). If the sample were taken off at a 2 inch depth, the overflow rate would be double and one would expect more solids in suspension at this point.

A similar method was used by the Bird Island Laboratory of the Buffalo Sewer Authority from 1938 to 1941. The technique consisted of adding 1100 ml. of sewage to a one liter graduated cylinder. After quiescent settling for a period of one hour, 800 ml. of the supernatant liquor were siphoned off in such a manner that the top layer of 100 ml. and bottom layer of 200 ml. were not disturbed. Suspended solids were determined on an aliquot portion of this withdrawn supernatant liquor by the Gooch Crucible method.

Other variations in technique are used or have been suggested elsewhere, but there are objections to all of these methods.

1. Obviously, the determination is of non-settleable solids and to obtain settleable solids requires the determination of suspended solids and the calculation of settleable solids by difference between suspended solids and non-settleable solids.
2. In a tall cylindrical graduate there is a certain amount of flocculation or precipitation of solid particles on the glass surface.
3. Flocculator jars size requires a larger volume of sample than is usually available in a composite sample of the average treatment plant.
4. Determinations depending on the Gooch test for suspended solids are open to the sampling errors involved in the Gooch test.

In an effort to minimize some of the disadvantages, and to arrive at a technique which, though admittedly partly empirical, offers practical possibilities, the authors agreed in 1941 upon the following procedure used since in Buffalo. The technique, by its very nature, defines settleable solids as that matter which will not stay in suspension during the settling period.

Procedure

(1) Determine the suspended solids in a sample of the sewage under investigation.

(2) Pour a well mixed sewage sample into a glass vessel not less than 3½in. in diameter, using a quantity of sample not less than 1 liter but preferably sufficient to insure a depth of 8 in. (The use of greater glass vessel diameters and larger volumes of sample, if available, may be desired to eliminate the possibility of disturbance of settled solids during the withdrawal of the portion for determination of non-settling solids. This difficulty may be almost entirely obviated through the use of a U-tube attachment on the intake end of the pipette or siphon used for the removal.)

(3) Allow to stand quiescent for one hour. Use of the theoretical detention period of the plant settling units is permissible if desired.

(4) Without disturbing the settled material or that which may be floating, remove 250 ml. of the sample from the center of the container at a point half way between the surface of the settled solids and the liquid surface.

(5) Determine the suspended solids in p.p.m. in all or in an aliquot portion of this supernatant liquor in accordance with standard procedures. The result is, of course, p.p.m. non-settling solids.

(6) Subtract this value from the total suspended solids in p.p.m. to obtain p.p.m. by weight of settleable solids.

It is believed that the results from this method more nearly represent the actual amount of suspended matter which is settleable under quiescent conditions, and that with this technique results obtained on the ratio of plant to laboratory removals will be more consistent as a measure of clarification efficiency.

References

(1) H. H. Wagenhals, E. J. Theriault and H. B. Hommon, "Sewage Treatment in the United States," U.S.P.H.S. Bull. No. 132, 1925.

(2) A. M. Buswell, A. L. Elder, C. V. Erickson and G. E. Symons, "New Method for Determination of Settling Solids," Part V, Illinois State Water Survey Bull. No. 29, 1930.

(3) Symposium: Standard Methods for the Examination of Sewage and Sewage Sludge: Comments by A. M. Buswell and G. E. Symons, "A New Method for the Determination of Settling Solids," Sewage Works Journal 2, 378-384 (1930).

(4) Standard Methods for the Examination of Water and Sewage, 8th Ed. P. 254.

(5) A. J. Fischer and A. Hillman, "Improved Classification by Preflocculation Without Chemicals," Sewage Works Journal 12, 280-302 (1940).

*Proposed for Standard Methods of Water and Sewage Analyses and accepted for 9th Edition.

IMPROVING THE OPERATION OF A SMALL TREATMENT PLANT

Wherein Inexpensive Contrivances Have Played an Important Part

By C. G. WEBER
Superintendent
Sewage Treatment Works, Annapolis, Maryland

THE Sewage Treatment Works, of Annapolis, having a capacity of 3 M.G.D., was placed in operation on September 4, 1936. The treatment consists of coarse screening, pre-chlorination and primary sedimentation with separate sludge digestion in heated fixed cover digesters. The sludge is dewatered on vacuum filters.

The sewage flows by gravity to a pumping station where it receives pre-chlorination. It is then pumped through a force main to the treatment works about one mile from the pumping station.

The treatment works consists of two 150,000 gallon clarifiers, provided with sludge removal and grease skimming mechanisms; two 180,000 gallon fixed cover sludge digesters, provided with gas collection and heating coil systems; a vacuum sludge filtering system; and a fully equipped control laboratory.

Chlorination Improvements

Chlorine was originally applied to the raw sewage at a manhole on the interceptor 25 feet ahead of the pumping station and into two 10,000 gallon wet wells (Fig. 1). With this arrangement there was considerable loss of chlorine which was not absorbed by the sewage. Chlorine permeated the shredder room and other parts of the pumping station causing considerable damage to metal parts. Applications of chlorine at the rate of 20 p.p.m. seldom produced chlorine residuals in the clarifier effluents and residuals in the influent reaching the plant were not at all uniform. Furthermore, there was rapid accumulation of sewage solids in the center of each wet well which increased the chlorine demand as it accumulated. Several feet of solids would accumulate in two or three days.

To overcome these difficulties the chlorine solution was piped to the wet wells and applied behind a deflector placed in the wells as shown in Fig. 1. By thus changing the direction of flow of the sewage through the wells the solids were prevented from accumulating. Chlorine, applied as shown at the baffle, was thoroughly mixed with the sewage and uniform residuals appeared at the treatment plant, with chlorine dosages of 15 p.p.m. Whereas, formerly there was little or no correlation between chlorine applied and chlorine residuals, complete correlation now exists and chlorine gas is no longer noticeable in the pumping station.

There are two W & T vacuum type automatic chlorinators, the water supply for which is obtained from the Severn River. When the temperature of the water drops to 47° F. the formation of chlorine hydrate has created considerable operating difficulty.

A 1,000 watt heater placed inside the chlorinator was helpful but not entirely satisfactory and very expensive to operate.

A hot water coil installed in the recirculating line of our hot water boiler, worked perfectly. During the past winter water pumped from directly under the ice was used without any difficulty.

Improvised Grit Chamber

The sewage treatment plant is not provided with a grit chamber. As a result the digester and clarifier pipes became choked with grit, making it very difficult to withdraw a sludge from either unit. At one cleaning about 6 tons of grit was removed from the clarifiers. Grit also accumulated rapidly in the digester. The Annapolis system is one of those assumedly separate domestic systems.

At the influent of the plant there is a diversion chamber provided with a swing gate. Immediately in front of this gate I installed a steel dam, which made a very satisfactory grit trap (Fig. 2). The accumulated grit is removed daily, and for the past two years we have had no grit trouble.

Sludge Pumping

The withdrawal of raw sludge from the clarifiers was through two telescopic valves, into a sludge well. From the well the sludge was pumped to the digesters. Since the well was open to the air there were numerous complaints of odors therefrom during its use. Furthermore this method of removal required about six hours.

To eliminate these difficulties we removed the valves and piping and connected directly to the sludge pump suction lines, and we measure the pumpage in minutes. A gage, installed in the laboratory, indicates when the sludge is thick or too thin for further pumping.

Sludge Disposal

For disposal of the digested sludge the plant was equipped with a sludge storage tank 11′ 6″ long by 9′ 6″ wide and 10′ deep, inside dimensions. The available storage space was about 900 cubic feet. The sludge from this tank was pumped to a conditioning or ferric mixing tank, equipped with air diffusers for mixing the sludge with lime and ferric chloride. Lime was added from a lime feeder and ferric chloride was fed from an Omega Solution Feeder. The conditioned sludge then flowed to an Oliver Vacuum Filter having 65 sq. ft. filter area.

Chemical Requirements

For the first year of operations (1937), we used on a dry sludge solids basis 7.7% ferric chloride and 21% lime. As our anhydrous ferric chloride then cost $3.62 per hundred and lime cost 55 cents per hundred, our cost of chemicals per ton of sludge solids was $7.88.

We soon found that lime caused rapid cloth binding. After dewatering about 12 tons of dry sludge solids the filter cloth had

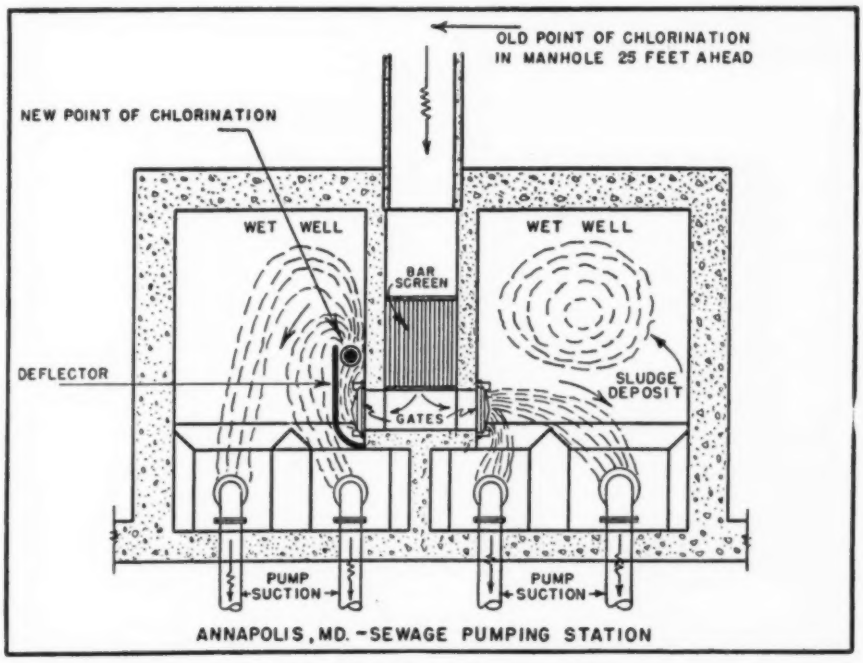


Fig. 1—Twin Pump Suction Wells Before and After Installing Baffle, Which Prevents Sludge Accumulations and Chlorine Loss.

*A paper presented before the 15th Annual Meeting of the Maryland-Delaware Water and Sewage Works Association.

to be acid washed. This represented about 51 hours of actual filter service per cloth dressing.

In 1938 we substituted a mechanical stirrer in our conditioning tank in place of the air mixing method, and found that without any lime at all we could get good filtration when using 7.3% ferric chloride. This method increased our filter cloth life by 200%. That is we dewatered 36 tons of sludge solids, or got about 153 hours of actual service out of each filter dressing. This development reduced the cost of our chemicals per ton of digested solids to about $5.29 per ton of digested solids, a saving of $2.59 (33%). Added to this was the saving in filter cloth costs.

In 1939 we managed to get the ferric chloride consumption down to 4.6%. However, about half of the sludge filtered was partially elutriated, as, with permission of Mr. A. L. Genter of Baltimore (owner of elutriation patents), we started experimenting with sludge elutriation in our sludge storage tank during 1939.

Elutriation Experiences

Our first trials with partial elutriation showed such definite savings in chemicals, labor power and filter cloth that we arranged to change over to a better method of elutriating, and of dosing the elutriated sludge with coagulant; also a simpler and more direct method of feeding the dosed sludge to the Oliver Filter.

First of all this necessitated placing a sloping concrete bottom in the existing sludge storage tank for elutriation purposes. Without this bottom experiments had proved that we couldn't obtain at all times a sludge of uniform solid content from the flat bottomed tank for a complete filter run. I also found that the elutriated sludge coagulated so easily with ferric chloride or alum solutions that we could do away with the mechanical stirring.

Changing the bottom of the sludge storage tank and equipping it with a sludge and water mixing trough and swivel pipe for syphoning off the clear wash water or elutriate, after allowing the washed solids to settle out, reduced the available elutriation settling space to about 650 cubic feet. However, this did not handicap our operations, but greatly improved our economies.

Settled Sewage Proves Best

For the last six months I have been experimenting with elutriation and making various changes to get the best economies from this treatment with our very limited means. We tried elutriating with well water, brackish bay water and settled sewage from the Dorr Clarifier. The latter proved the most effective and least costly source of elutriate water for our sludge. The brackish bay water, nearest our plant, actually produced a wetter cake and required slightly more ferric chloride. This was somewhat contrary to expectations.

Arrangements

Our present set-up for elutriating and conditioning the digested sludge is shown in Fig. 2.

One of the telescopic sludge valves removed from the raw sludge well was placed in a 50 gallon steel drum on top of the sludge elutriation tank. When this valve is properly set by the hand-wheel there is just enough gravity head from the digestion tank to feed a steady stream of digested sludge into the drum. Settled sewage is pumped into the same drum, mixing with the digested sludge. The mixture then overflows a vertical pipe standing in the open drum and flows to the elutriation settling tank through a manhole on top of this tank. As the drawings show, the sludge and water are thoroughly mixed in a trough located in the top of the settling tank. The trough is equipped with baffles staggered at an angle. The mixture then flows into the tank, until it is practically full. After the solids have settled out, the clear supernatant is syphoned off by means of a 4-inch swivel overflow drain. This supernatant flows to the plant sump and is pumped back to the primary clarifier. The settled washed sludge is pumped to the conditioning tank, which will be described later.

In Fig. 3 is pictured the simple arrangement adopted for pumping elutriating water from the overflow trough of the primary Dorr clarifier through the window of the filter building to "washer tank" on top of the elutriation tank.

Results

At present we are dewatering elutriated sludge with about 1.7% ferric chloride and no lime. The price of ferric chloride has advanced from $3.62 per hundred in 1937 to $4.98 per hundred at present, or almost 38% increase. Despite this fact our present cost for ferric chloride per ton of sludge solids is but $1.69, which is $6.19 (78.5%) less per ton of sludge solids than in 1937 and $3.60 (68%) less per ton than in 1938.

To be entirely fair to our present elutriation results, if we were now paying the price of $3.62 per hundred for ferric chloride like in 1938, our present cost per ton of sludge solids

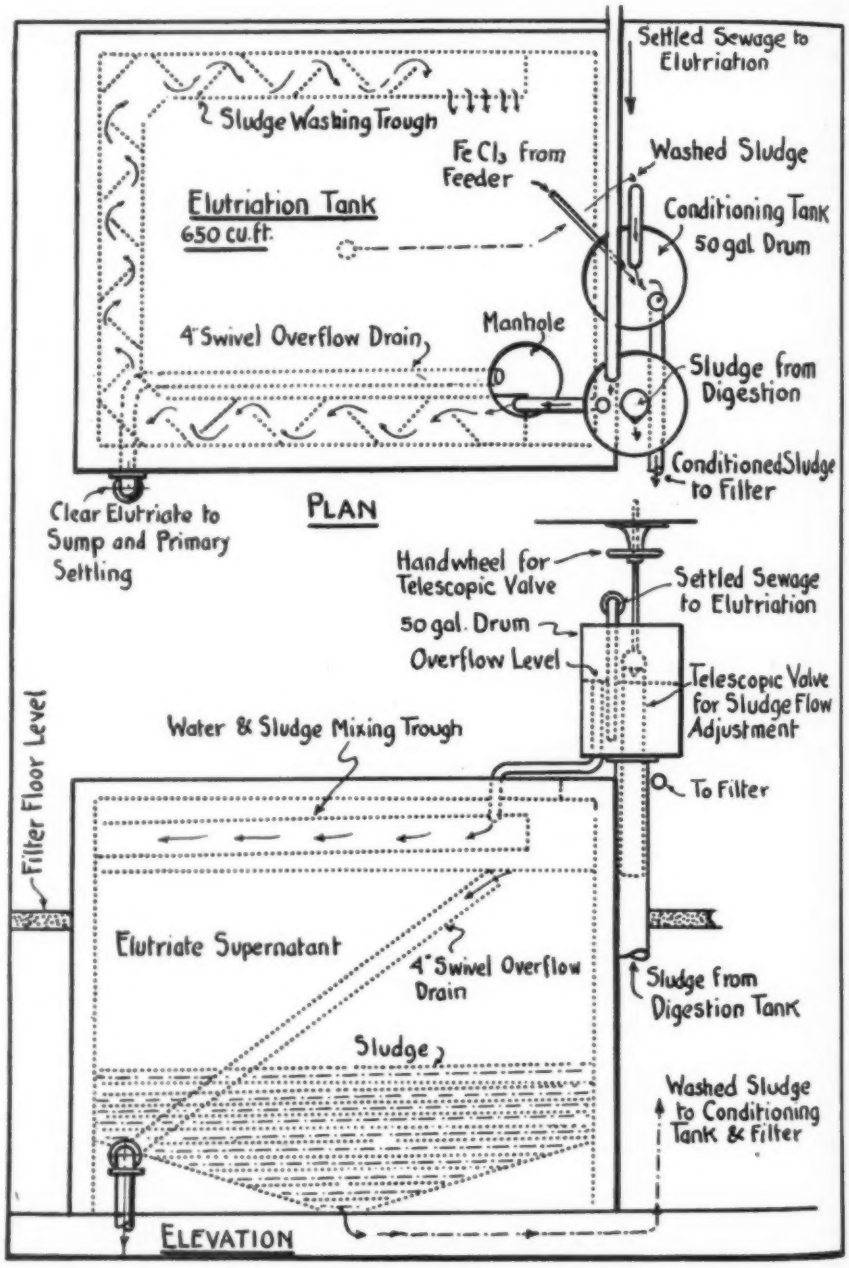


Fig. 2—Sludge Elutriation Arrangement
Sludge Storage Tank Converted Into Elutriator, Employing Settled Sewage as the Elutriating Water. Note Adjustable Mixing Tank at Top.

dewatered for ferric chloride would be $1.23 and the savings per ton of sludge solids dewatered would be $6.65, or 84.5% less than in 1937; and $4.06, or almost 77% less than in 1938.

However, with elutriated sludge at Annapolis there are other means of cutting chemical cost. We have made very successful filter runs on elutriated sludge when using commercial alum from our water treatment plant. Compared to anhydrous ferric-chloride, about three times as much commercial alum is required and the price of alum vs. ferric-chloride will determine the material to be used in the future. We tried alum on unelutriated sludge and found it unsatisfactory, as the conditioned sludge was difficult to filter and required much larger doses.

Other Savings

The savings in chemical costs are only a part of the story of elutriation economy. Our filter yields at this low chemical addition are from 8 to 10 pounds per square foot per hour and our filtering time, labor and electric current consumption has been cut in half. During 1939 when about half of our sludge was elutriated our filter blanket lasted for 123 tons of cake or over 520 hours of active service. We now hope to get 300 tons or about 1,200 hours of service out of a blanket costing about $27.

Sludge Mixing Arrangement

The details of our present sludge conditioning tank are shown in Fig. 4. This tank was made out of a 50-gallon oil drum and has no mechanical stirrer or air diffuser, so power for this purpose has been eliminated. By properly jetting the small stream of ferric chloride from the Omega Feeder into the inflowing stream of washed sludge, the sludge and ferric chloride or alum solution are thoroughly mixed. This is done by the agitation resulting from the inflowing sludge stream falling into the pool of sludge in the bottom of the small tank or drum. This pool is about seven inches deep and the inflowing stream displaces an equivalent amount out of the drum through a vertical pipe nipple overflow. This nipple can be lifted out of the drum at the end of filter runs so all of the conditioned sludge will be drained from the system to the filter.

With elutriated sludge this intimate flash mixing produces an excellent floc almost instantly. The conditioned sludge displaced from the drum flows downward through a feed pipe, through the end of the Oliver Filter tank to the center point without any delay. In other words the feed pipe is not the usual inverted syphon. We found that the inverted syphon was very unsatisfactory. Furthermore, feeding the sludge directly into one end of the filter resulted in good cake on half of the filter nearest the sludge inlet and poor cake on the other end of the drum. So we extended the pipe to the center.

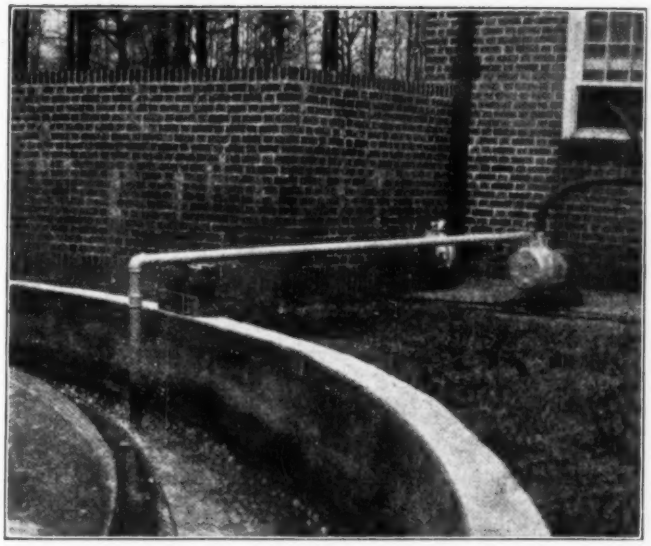


Fig. 3—Portable Homelite Pump
Delivers Settled Sewage to the Mixing "Washer Tank" (Fig. 3) at a Cost of 13c per Day.

In operating elutriation and filtration our set-up does not permit withdrawing clear elutriate while we are washing sludge because our settling tank is too small. However, as we filter sludge but two or three times every week, we draw the sludge from digester and wash it during the day preceding filtration. We then let the sludge settle over night, which produces a very clear elutriate and thick sludge. We syphon the elutriate off on the following morning and pump the settled washed sludge to

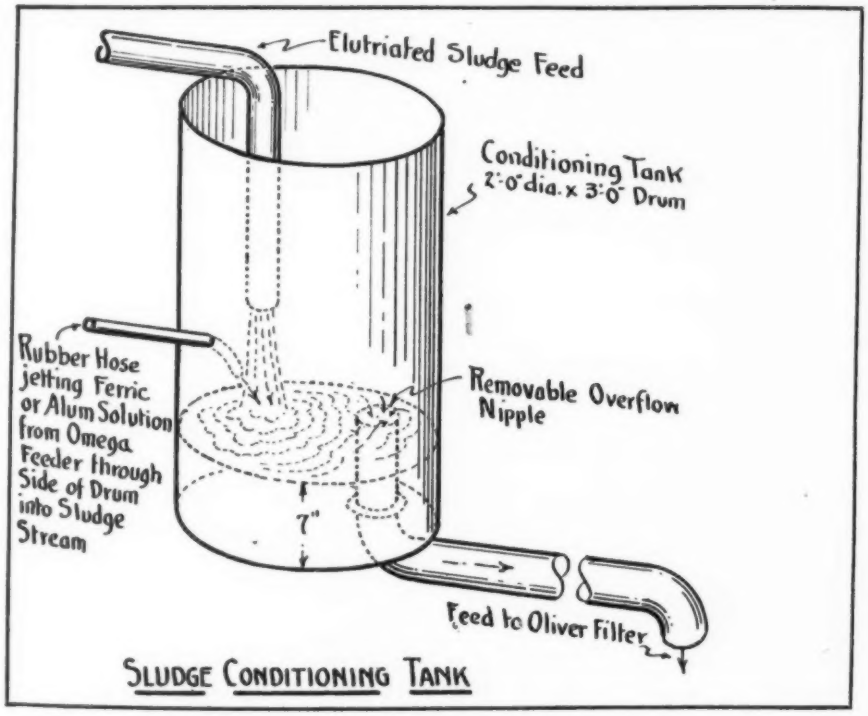

Elutriated Sludge Feed
Conditioning Tank
2'-0" dia. x 3'-0" Drum
Rubber Hose jetting Ferric or Alum Solution from Omega Feeder through Side of Drum into Sludge Stream
Removable Overflow Nipple
7"
Feed to Oliver Filter
SLUDGE CONDITIONING TANK

Fig. 4—Simple Sludge Conditioning Tank
From a 50-Gal. Oil Drum This Effective Mixing Unit Was Constructed. Seems to Be All That's Required for Elutriated Sludge.

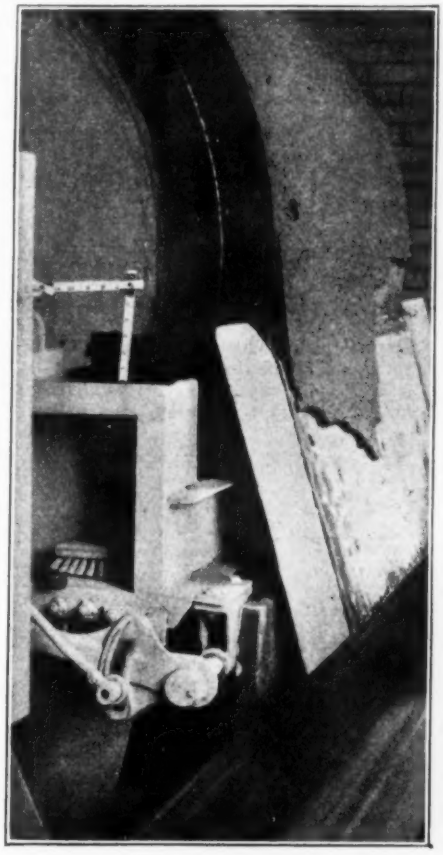


Fig. 5—Filter Cake
This ¾" Cake (8 to 10 lbs. dry solids/sq. ft./hr.) is Characteristic of Present Operations.

sludge conditioning and the filter. We generally use about four voulmes of elutriating water (settled sewage) to one volume of sludge. We filter about 2,200 pounds of sludge solids during one filter run and take about 3 hours to complete the run. Ordinarily we filter about 156 days every year, or three times a week.

Fig. 5 shows the filter cake now obtained from the elutriated sludge. Four cake thicknesses measure three inches, meaning the cake is about ¾" thick.

"Annapolis" Sludge Weigh-Recorder

Previous to the use of elutriation we had estimated the sludge solids dewatered by sampling the sludge collected in the storage tank and then measuring the cubic feet and pounds of sludge withdrawn from the tank by any filter run. When elutriation was adopted this method was not practical. I then devised an automatic self-dumping and recording sludge scale, shown in Figs. 6 and 7. The first is a sketch of this device. As can be seen this is controlled by adjustable weights, and the whole is attached to the supporting frame of the filter cake belt conveyor. At present this dumping scale is set, by the "adjusting weight" on the arm locking into the spring bolt, to release the hinged bottom door when exactly 33.3 pounds of sludge cake has accumulated in the scale box from the belt conveyor. The scale is frequently checked by diverting a dumped load to a pan on an ordinary beam scale. An ordinary revolution counter, fastened to the conveyor frame, is attached by a rod and spring to the weighted arm which closes the box bottom after each load is dumped into the truck below the box. The cake is sampled for moisture and solids determinations and by multiplying the number of cake dumps recorded on the counter by the weight of each dump and the percent solids present, the dry pounds of cake solids per run are easily obtained. The photograph (Fig. 7) shows this inexpensive and accurate device with the hinged door open above the plant truck.

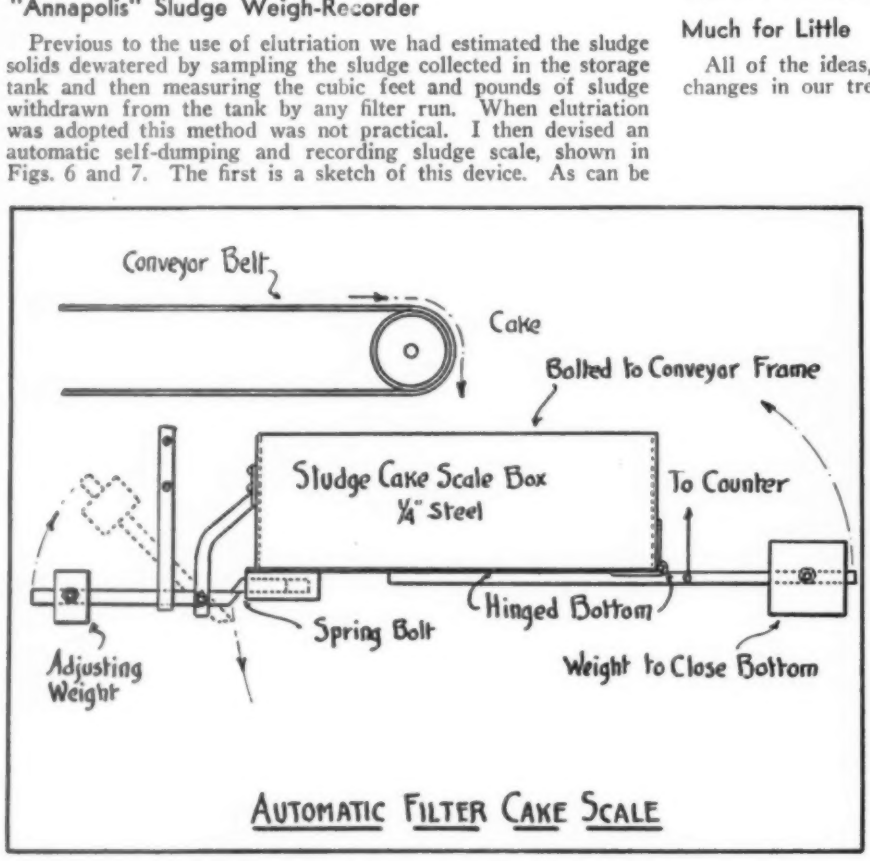


Fig. 6—"Annapolis" Automatic Sludge-Weigh-Recorder
Just a Home Made "Gadget," but It Does a Good Job of Giving Us a Record of Sludge Weight and Dumps Automatically—See Fig. 7.

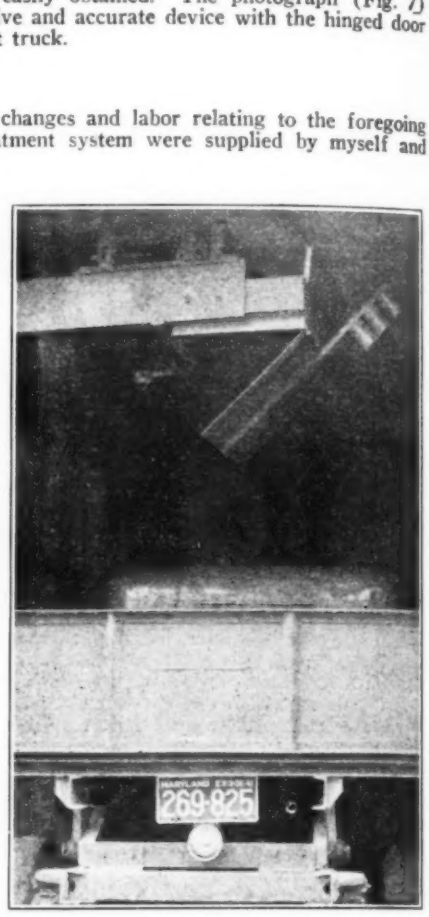


Fig. 7—The Self Dumping Weight-Recorder
Has Just Released Its Load of 33.3 lbs. of Filter Cake Into Truck—See Fig. 6.

Much for Little

All of the ideas, changes and labor relating to the foregoing changes in our treatment system were supplied by myself and others of the operating force. The cost of the materials and structural changes involved in elutriation, new sludge conditioning method and filter feeding and cake weighing amounted to less than fifty dollars.

The cost of pumping clarifier overflow (settled sewage), for elutriation with the little Homelite Portable Pump is very little, namely 13 cents per day of operation. This cost is more than offset by our saving in power for filtration.

Decimal Equivalents
of 8ths, 16ths, 32ds, and 64ths of an Inch

8ths				
1/8 = .125	9/16 = .5625	17/32 = .53125	9/64 = .140625	37/64 = .578125
1/4 = .250	11/16 = .6875	19/32 = .59375	11/64 = .171875	39/64 = .609375
3/8 = .375	13/16 = .8125	21/32 = .65625	13/64 = .203125	41/64 = .640625
1/2 = .500	15/16 = .9375	23/32 = .71875	15/64 = .234375	43/64 = .671875
5/8 = .625		25/32 = .78125	17/64 = .265625	45/64 = .703125
3/4 = .750	32ds	27/32 = .84375	19/64 = .296875	47/64 = .734375
7/8 = .875	1/32 = .03125	29/32 = .90625	21/64 = .328125	49/64 = .765625
	3/32 = .09375	31/32 = .96875	23/64 = .359375	51/64 = .796875
16ths	5/32 = .15625		25/64 = .390625	53/64 = .828125
1/16 = .0625	7/32 = .21875	64ths	27/64 = .421875	55/64 = .859375
3/16 = .1875	9/32 = .28125	1/64 = .015625	29/64 = .453125	57/64 = .890625
5/16 = .3125	11/32 = .34375	3/64 = .046875	31/64 = .484375	59/64 = .921875
7/16 = .4375	13/32 = .40625	5/64 = .078125	33/64 = .515625	61/64 = .953125
	15/32 = .46875	7/64 = .109375	35/64 = .546875	63/64 = .984375

A LUBRICATION CHECK SHEET

By ROBT. C. URBAN
San. Engr., Corps of Engrs., War Department

THE Lubrication Check Sheet shown below will be of help in normal times of operation as well as when adverse conditions prevail.

There are three steps in setting up a lubrication check sheet.

1. Locate every piece of equipment needing grease or oil as a lubricant or as protection.

2. Study the manufacturers maintenance instructions to determine where and when to lubricate and what kind of lubricant to use. Inasmuch as many manufacturers have particular preferences in the matter of lubricants, this may lead to a large number of different types of lubricants and as many grease guns.

It may be much simpler to call in a lubrication engineer from any of the recognized oil companies and have him prepare a lubrication specification sheet for every point of lubrication you have listed.

In this way it may be possible to cut down on the number of oils and greases that will have to be stocked. As few as two oils and two greases may suffice.

3. Prepare the Lubrication Check Sheet following the general idea of the accompanying illustration. List all of the units needing lubrication, the necessary lubrication points, the type of lubricant recommended for each point. Allow space for date of lubrication and initials of operator performing the job.

There is no doubt that the Lubrication Check Sheet will become more and more important to the proper maintenance of operating equipment.

MASTER LUBRICATION CHECK SHEET

1945

GREASE: "HEAVY" - X CO. NO. 2 HEAVY DUTY
"CUP" - X CO NO. 31 CUP GREASE

OIL: "20" - X CO. NO. 341 S.A.E. 20
"90" - X CO. GEAR OIL 90

UNIT	FITTING TYPE	FITTING NO.		TYPE OF OIL OR GREASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SEWAGE PUMP HOUSE																
SEWAGE MOTORS (2) BEARINGS	PIN	2 EA.	G	"HEAVY"												
SEWAGE PUMPS (2) BEARINGS	PIN	2 EA.	G	"HEAVY"												
GREASE SEALS (2)	PRESSURE CUP	1 EA.	G	"CUP"	—		CHECK DAILY & ADD AS REQUIRED									—
VACUUM MOTOR BEARINGS	PIN	2	G	"HEAVY"												
VACUUM PUMP	SIGHT FEED	1	O	S.A.E. 10	—		CHECK DAILY & ADD AS REQUIRED									—
FLOAT RODS (2)	"SURFACE"	1 EA.	O	"20"	2 T.M	1 AK	5 F.M	6 F.M								
SCREENINGS GRINDER																
GEAR REDUCER	PLUG	1	O	"20"	CHANGE 2 T.M				CHANGE				CHANGE			
(" ")	PLUG	1	O	"20"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
LOWER SHAFT BEARING	PUSH	1	G	"HEAVY"	—		TWELVE STROKES DAILY									—
MOTOR BEARING	PIN	1	G	"HEAVY"	2 T.M											
SLUDGE COLLECTOR																
GEAR REDUCER	PLUG	1	O	"90"	CHANGE 8 T.M						CHANGE					
(" ")	PLUG	1	O	"90"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
SPROCKET BEARING	PUSH	1	G	"CUP"	GREASE WEEKLY — SEE WEEKLY CHECK SHEET											
MOTOR BEARING	PLUG	1	G	MANUFACTURER'S SPECIAL	8 T.M											
SLUDGE PUMP																
MOTOR BEARINGS	PUSH	2	G	"HEAVY"												
MAIN BEARINGS	PUSH	4	G	"HEAVY"	8 T.M	1 AK	5 F.M.	6 F.M								
ECCENTRIC BEARING	SIGHT FEED	1	O	"20"	—		CHECK DAILY & ADD AS REQUIRED									—
CROSS HEAD BEARING	"SURFACE"	1	O	"20"	—		CHECK DAILY AND KEEP PIN COVERED									—
GEAR REDUCER	PLUG	1	O	"90"	CHANGE 4 T.M						CHANGE					
(" ")	PLUG	1	O	"90"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
CONNECTING ROD	GREASE CUP	1	G	"CUP"	—		GIVE SLIGHT TURN DAILY									—
TRICKLING FILTER																
BEARINGS	PIN	5	G	"CUP"	10 T.M	8 AK	2 F.M.	3 F.M								
ROTARY VENTILATORS (3)																
TOP BEARING	"CUP"	1 EA.	G	"CUP"												
BOTTOM BEARING	"CUP"	1 EA.	G	GRAPHITE MEDIUM												
HOT WATER CIRCULATORS (2)																
MOTOR BEARING	OIL CUP	2 EA.	O	"20"	7 AK	14 F.M	19 F.M	20 F.M.								
SHAFT BEARING	GREASE CUP	1 EA.	G	MANUFACTURER'S SPECIAL	7 AK	14 F.M	19 F.M.	20 F.M								
FLOATING COVER																
ROLLER (6) BEARINGS	PIN	2 EA.	G	"CUP"												
VALVES																
6" SCUM WELL PLUG VALVE	PLUG	1	G	PETROLEUM JELLY	—		KEEP VALVES TURNING EASILY									—
OTHER 6" PLUG VALVES	PLUG	1 EA.	G	MANUFACTURER'S SPECIAL	—		KEEP VALVES TURNING EASILY									—
GAS LINE PLUG VALVES	PLUG	1 EA.	G	MANUFACTURER'S SPECIAL	—		KEEP VALVES TURNING EASILY									—
WORM STEM VALVES	"SURFACE"	1 EA.	G	"CUP"	—		KEEP STEM SURFACE COVERED									—
PRESSURE RELIEF F.T. UNITS																
PRESSURE-VACUUM F.T. UNIT	LEATHER DIAPHRAM	1	O	NEATSFOOT		15 F.M		23 F.M.								
FLAME TRAP UNIT (SPRING)	"SURFACE"	1	G	"CUP"		15 F.M		23 F.M								
PRESSURE F.T. UNIT	LEATHER DIAPHRAM	1	O	NEATSFOOT		15 F.M		23 F.M								
(" ") (SPRING)	"SURFACE"	1	G	"CUP"		15 F.M		23 F.M								
TELL-TALE																
CHAIN	"SURFACE"	1	G	"CUP"		15 F.M		24 F.M								
MOTORIZED VALVE																
SLIDE	"SURFACE"	1	G	"CUP"				25 F.M								
MOVING PARTS	BEARINGS	EA.	O	"90"				26 F.M								
DAMPER MOTOR																
MOTOR BEARING	"OIL CUP"	1	O	S.A.E. 10		F.M.										
CHLORINATOR																
METAL	"SURFACE"	EA.	G	PETROLEUM JELLY	KEEP ALL METAL TUBING, VALVES, PARTS, ETC., COVERED.											

OPERATING LOG FOR A SMALL SEWAGE PLANT

By A. A. HIRSCH
State Department of Education
Baton Rouge, Louisiana

THE desirability of complete record keeping about a sewage plant is generally recognized, but operating logs are often so bulky, and time consuming to attend, that operators frequently regard them with disfavor. A properly planned log should contain only pertinent and useful data; its form should be streamlined to expedite the recording of necessary figures. Excessive use of columns to record other than regularly recurrent data should be avoided. Aid should be included for easy reference to records of previous periods.

The application of these principles to the design of a daily operating report for a small plant providing primary settling in an Imhoff Tank and secondary trickling filter treatment is illustrated in the accompanying drawing. Obviously, the information carried and form best adapted will vary with the size and type of plant; however, the essential points as enumerated below can always be employed to advantage. In the illustrated log will be noted columns for customary daily data; a sheet covers a month's operation. As in many plants, the blanks are printed in different colors for duplicates or triplicates, with stiff cover binding. Groups of related data are separated by heavy vertical ruling; every fifth date line is also drawn heavy to facilitate space location. The column headings are all self explanatory, excepting the codes, which will be discussed below. Mechanical and operational data are segregated from the chemical test results. Customary rulings appear at the bottom of the sheet for the monthly summary. A liberal width is reserved in the remarks column for infrequent details or a condensed diary. Additional notes of this character can be written on the back of the sheet with proper reference on the corresponding date line. The extra column, preceding the "Remarks" column (now blank), is provided for possible future need.

Distinctive Features

It is to the following five features, some of them unique, that attention is specifically directed:

1. *Size of Sheet.* The sheet measures 11 by 16⅝ inches. This is a convenient size, its length being the same as that of an ordinary letter size typewriter sheet, while its width is slightly less than double a letter sheet. Records detached from the blank book may be folded slightly beyond the middle to fit a file folder exactly as would a letter. Using the same crease, the left margin extends out as a single thickness almost the full ruled width, thereby permitting perforation to fit ordinary size looseleaf binders.

2. *Double Date Column.* Date columns are printed at both sides of the tabulated data in order to locate particular date spaces by easy glances and with less chance for error.

3. *Coding.* All routine descriptive remarks are keyed to condense this information. The identity and sequence of units in service are recorded by code in the proper column. Points of chlorine application are denoted by a key letter placed behind the total quantity used. A suitable legend explaining the code is placed off to the right of the sheet so that the information will always be intelligible. By way of example, the notation in the units in use column T2E-R1-F2 would signify on that date Imhoff tank No. 2 flowed eastward and rotary filter No. 1 with final settling tank No. 2 were in service. In the chlorine quantity per day column the data 5.5-EF would mean that this weight of chlorine, in pounds, was being divided between the Imhoff effluent and the final settling tank.

4. *Occasional Information Boxed Separately.* Infrequent data are posted in a side space to conserve room in the main taubulations, where this type of information would be difficult to locate. A special tabulation is made to the right of the sheet to record sludge drawoffs. Service connections also are displayed in an individual box.

5. *Marginal Indexing.* Marginal tabs for quick location of past records in bound volumes of monthly sheets is provided by printing the edge of the sheet with names of the months. In use, all other names except for the month concerned are cut off. If the sheet is folded during filing, the operator may print the name of the month on the reverse of the tab also.

A log of this type is presently giving satisfaction at the Rayne, La., disposal plant, where Mr. E. J. Bertrand is superintendent, and Mr. Pat Spell, operator. With functionally arranged sheets, record keeping is expedited and the value of previous logs for reference is enhanced.

NOZZLE REPLACEMENT ON TRICKLING FILTERS

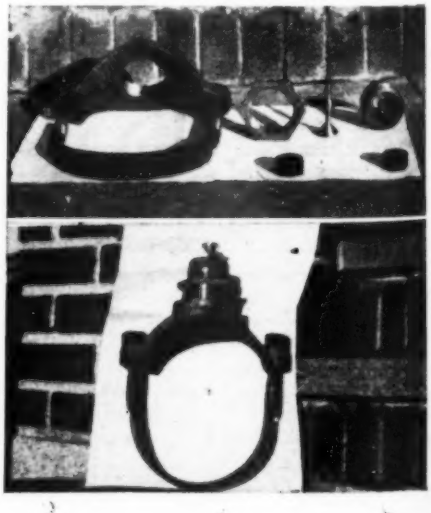
By ROY S. LANPHEAR
Worcester, Mass.

FLUSHING of the lateral distributors of the trickling filters at Worcester is done once each week by removing the end nozzle in each line (several at a time), and allowing the dosing tank siphons to operate once or twice. The threads in the pipe openings, into which the nozzles were screwed, were destroyed after a few months of this routine operation. Cast iron pipe, brass nozzles and a sewage containing strong acid and alkaline industrial waste liquors were also factors in such destruction.

Saddles, with washers and U-bolts, were first used. When the threads in a saddle gave out, a new saddle was installed. This operation proved successful and was used for some time. Additional purchases indicated that while the method was a success, the expense was quite an item in the cost of filter operation. Apparently galvanic corrosion was at the root of the thread wearing difficulty.

A later improvement was the use of a 2½x2-inch brass bushing in the saddle opening. This left the contact of the iron and brass threads undisturbed when removing the nozzles. No difficulty is now experienced and saddles with the bushings have been in use since May 1937. In lots of 200 the cost of the saddles, strap-type U-bolts, and bushings, was 84, 58½ and 47 cents each, respectively.

The accompanying cut shows the several component parts of the successful assembly.



R-215

SMALLTOWN, LOUISIANA

SEWAGE TREATMENT PLANT OPERATING REPORT

MONTH OF _____ 194__

Date	Sewage Flow MGD	POWER Reading KWHr	POWER Consmpn KWHr	UNITS IN USE (CODE)	TEMP °F Air	TEMP °F Sewage	Rainfall in.	SETTLEABLE SOLIDS ml/L Raw	Settled	Final	% Removal	pH Raw	Settled	Final	Sludge	Relative Stability %	CHLORINE Cylinder Weight Setting	Quantity #/Day	Points Applied	Dose ppm.	Residual p.p.m.
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Date	REMARKS
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Avg	
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SLUDGE WITHDRAWLS Date	Imhoff Tank No.	Amount Cu. Ft.

Service Connections at End of Month

CODES

Plant Units
T - Imhoff Tank - 1-2
Flow - (E)ast-(W)est
R - Rotary Filter - 1-2
F - Final Set. Tank - 1-2

Chlorine Points
R - Raw Sewage
E - Imhoff Effluent
F - Final Set. Tank

_____ OPERATOR

_____ SUPERINTENDENT

JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC.

W. & S. W. — REFERENCE & DATA — 1946

Operating Log for Small Sewage Plants

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THE JEFFREY MANUFACTURING COMPANY

ESTABLISHED 1877

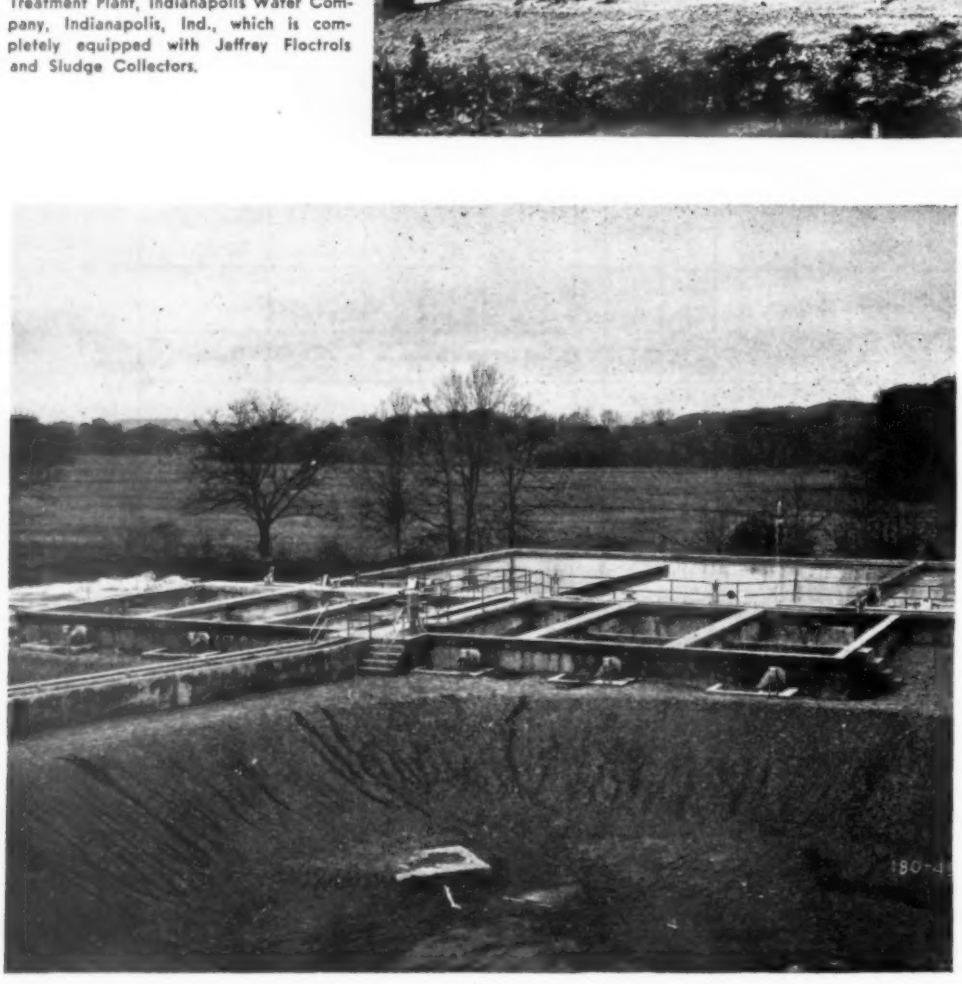
996-99 North Fourth Street, Columbus 16, Ohio

BALTIMORE 2, MD., Munsey Bldg.
BIRMINGHAM 3, 2210 Third Ave., N.
BOSTON 16, 38 Newbury Street
BUFFALO 2, Jackson Building
CHICAGO 1, Bell Bldg.
CINCINNATI 2, Carew Tower
CLEVELAND 13, Rockefeller Bldg.
DENVER 2, Ernest & Cranmer Bldg.
DETROIT 13, 5808 St. Jean Ave.
HARLAN, Kentucky
HOUSTON 5, TEXAS, 3748 Rice Blvd.
HUNTINGTON 19, W. VA.
Robson-Prichard Building
JACKSONVILLE, Florida
MILWAUKEE 2, 735 No. Water Street
NEW YORK 7, 30 Church Street
PHILADELPHIA 3, Broad St. Station Bldg.
PITTSBURGH 22, Oliver Bldg.
SALT LAKE CITY 1, 101 W. 2nd South St.
ST. LOUIS 3, 3015 Locust St.
SCRANTON 3, 122 Adams Avenue

Jeffrey Mfg. Co. Ltd. of Canada: Head Office, Montreal; Branch Offices, Toronto, Hamilton, Calgary, Vancouver

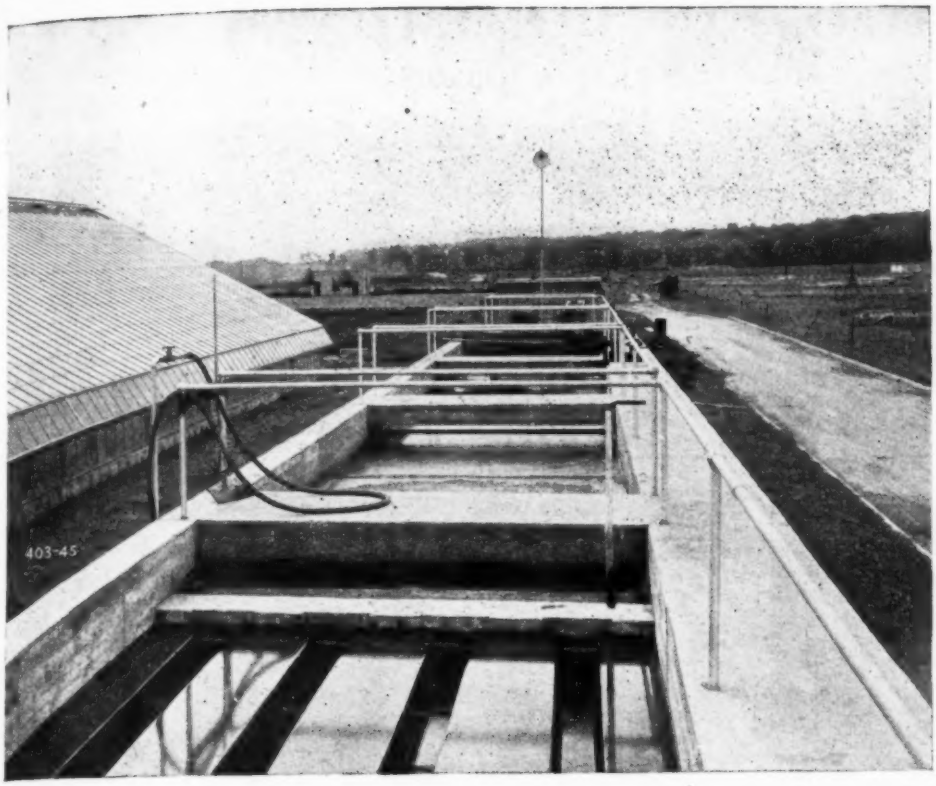
A complete line of equipment for Water, Sewage and Industrial Waste Treatment as well as Biofiltration Systems for Purification of Sewage and Concentrated Organic Wastes: Bar Screens, Grit Washers (patented), Grit and Sludge Collectors (patented), Floctrols (slow-mixing equipment) (patented), Sludge Elevators, Screenings and Garbage Grinders (patented), Conveyors, Chains, and Bearings.

View at right shows a 16 MGD Water Treatment Plant, Indianapolis Water Company, Indianapolis, Ind., which is completely equipped with Jeffrey Floctrols and Sludge Collectors.



View at left shows six Jeffrey Floctrols in Water Softening Plant at Newark, Ohio.

The Jeffrey Manufacturing Company of Columbus, Ohio, is prepared to grant licenses to all ultimate consumers for a reasonable royalty obtainable upon application, under any or all of its following patents: 1,999,863 — 2,102,990 — 2,160,534 — 2,237,172 — 2,266,097 — 2,268,461 — 2,291,121 — 2,291,641 — 2,324,637.



View at left shows a Concentration Tank for Humus Sludge at Dayton, Ohio. Concentrated sludge is 3.5% solid. Equipment consists of Jeffrey Floctrol and Sludge Collector.

Jeffrey **JIGRIT** Washer

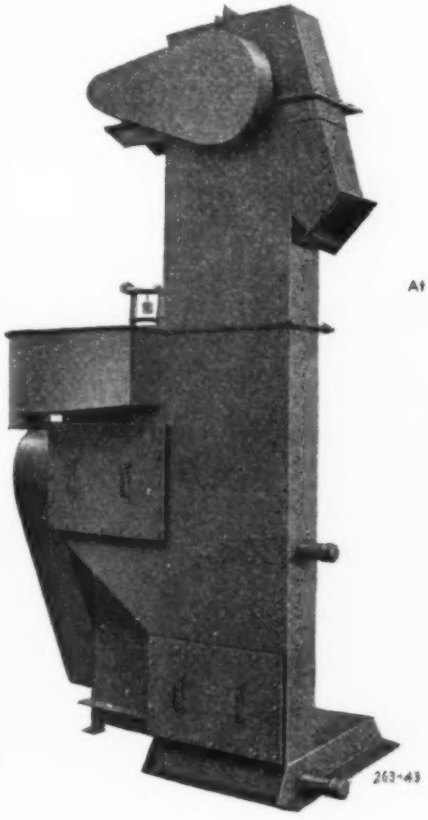
(REG. U. S. PAT. OFFICE)

Jeffrey patented JIGRIT Washer is now built in three sizes ranging in capacity from one ton to fourteen tons per hour, offering these advantages:

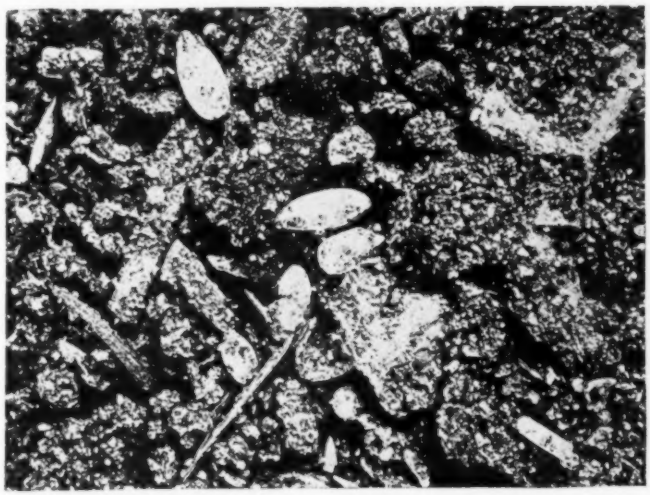
1—Removes 90% of putrescible solids.

2—Washed grit contains no organic seeds or unsightly material—can be used as fill without creating a nuisance.

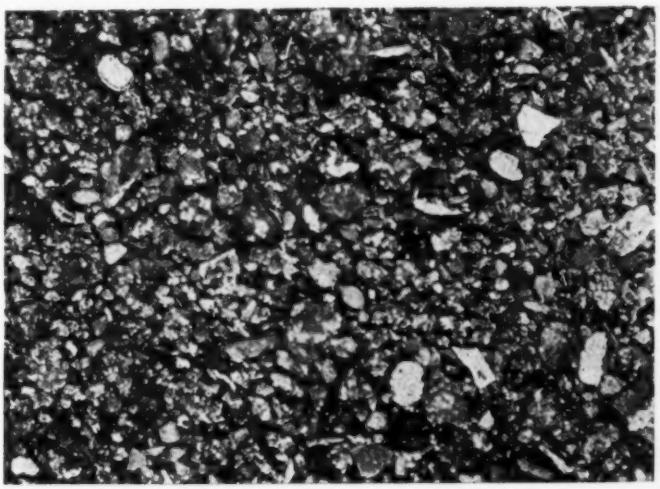
3—Recovers practically all of the +65 mesh grit.



At left—Jeffrey No. 4 JIGRIT Washer



Magnified view of unwashed sewage grit



Magnified view of washed grit after passing through Jeffrey JIGRIT Washer

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

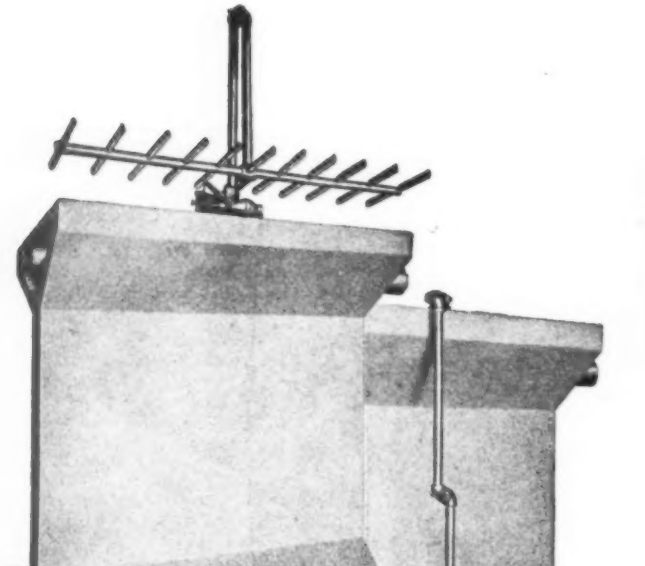


Fig. 2914—Swing Diffusers
Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

Fig. 2349 (right)**—Combination Aerator-Clarifier**
providing complete treatment of sewage without odor nuisance and with minimum manual operation. Ideal for housing projects, small camps, institutions and small towns. Over 100 units operating successfully. Ask for Bulletin 128-K

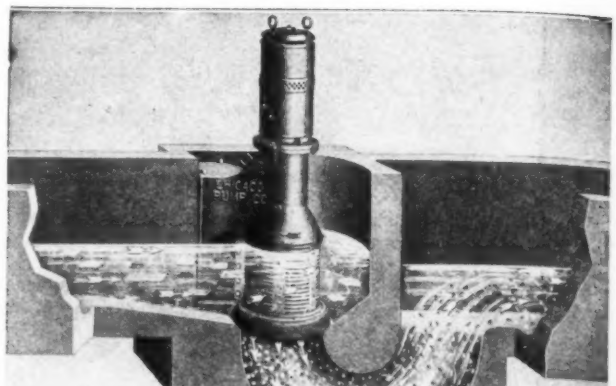


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel. Ask for Bulletin 185.

Fig. 2504—Vertical Open-Shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

Fig. 1860—Scru-Peller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer Keeps solids from basin and pumps. Impeller handles water only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

SLUDGE PUMPING

A Discussion on Pumps, Installation, Design and Operating Problems

By S. E. KAPPE, Engineer

Chicago Pump Co., Washington, D. C.

THE purpose of this paper is to discuss briefly the problems encountered in moving sewage sludges from one tank to another. The paper covers the type of pumps used for sludge pumping, their respective advantages and disadvantages, the design of sludge lines, and the problems involved in sludge pumping and their solution. Since the writer's firm manufactures all types of pumps commonly used for sludge pumping, an opportunity is presented to discuss the subject from experience gathered in actual plant operation.

The Plunger Pump

The plunger pump is popular because of its positive displacement characteristics. It will pump mixtures of sludges, sewage gases, and air equally as well as liquids. It is this self-priming feature which makes the pump more readily primed than a centrifugal pump where a suction lift is involved, or high spots exist in the suction line where gases may accumulate. Beyond this characteristic, however, it is questionable whether this pump offers any other superiority over other well-designed sludge pumps.

The following are some of the objectionable features of the plunger pump. The pump is often very noisy, complaint being frequent that it pounds and knocks. Such pounding is due to the reversal stresses in the different parts of the pump, caused by the starting and stopping of the column of heavy fluid on the suction and discharge side at each stroke. This noise can often be minimized by providing adequate air chambers on both the suction and discharge sides, and by reducing the pump speed. The reverse flow of the sludge through the valves is commonly known as slippage. It reduces the delivery of the pump, and, as a consequence, its efficiency.

Another objectionable feature is the maintenance required to keep the packing tight. If the packing is too soft, too loose, or improperly placed, the operator might find himself as well as the walls and floor sprayed with sludge, leaving an unpleasant taste and a messy cleaning job. Then if the packing is *too* tight, scored pistons or cylinders and broken shear pins may be experienced. The amount of grit in the sludge will govern the life of the packing and, likewise, the wear to which the pistons and cylinders will be subject. An effective grit chamber at the head of the treatment plant is an asset in prolonging the life of sludge pumps, and plunger type pumps in particular.

The valves on the suction and discharge side, whether they be ball or flap type, often require frequent attention. Clogging material will accumulate under the valve seats and around the valves and may cause the pump to stop delivering completely. The valves should, therefore, be inspected periodically. Poor valves may swell and stick, or the rubber may soften or become worn down by gritty material to a size that can be forced into the pump or piping.

The Centrifugal Pump

Centrifugal sludge pumps cannot, like the plunger pump, handle sludges containing large amounts of gas or air. If there is too much sludge gas and air present, the centrifugal pump becomes gas-bound. Therefore, it can readily be seen that this type of pump is not as adaptable for use where there is a suction lift or where air or gas pockets can exist in suction lines. It is also necessary to prevent air from being sucked in through the stuffing boxes. For this purpose waterseals must be provided. This does not mean that this type pump cannot be used for suction lift duty. On the contrary, there are many centrifugal sludge pumps operating successfully under suction lifts up to fifteen feet.

When suction lift duty is involved, a priming chamber should be provided. This priming chamber must perform the dual service of automatic priming and removing accumulated air and gases from the suction line. Where a suction lift exists, the discharge nozzle of a horizontal centrifugal pump should be on the top side of the volute, either parallel to the floor or in a vertical upright position. If the discharge nozzle faces downward, or is placed on the bottom of the volute parallel to the floor, the pump can not be readily primed because there is no way for the entrapped air and gas in the top of the casing to escape.

In may surprise some to hear that, in general, the so-called non-clog type centrifual pump has not proven very satisfactory for sludge pumping service. The smaller the capacity, the more clogging difficulties could be expected from the concentrated amounts of hair, rags, and stringy material in the sludge. Best results are obtained if the suction line is short. The whirling action induced on the suction side of this type pump is not conducive to trouble-free operation. The impeller motion causes the sludge in the suction pipe to rotate in a whirling or spiral motion for a distance of fifteen feet or more. This whirling action will often twist and enmesh the concentrated hair, rags, and stringy material in the sludge into ropes, or wads, which will then clog the impeller of so-called non-clog pumps. Another objection is that the centrifugal force at the suction eye of the impeller may partially dewater the sludge and thus cause clogging.

Centrifugal pumps perform best under positive suction head conditions. This type pump is preferred by many because its operation is quiet and clean, and there are no ball valves or flap valves incorporated which would need periodic attention.

Force-Feed Centrifugals

In spite of all the inherent weaknesses of the plunger pump, until the development of special force feeding centrifugal pumps, the plunger pump was the best available for pumping sludges, particularly in the small capacity ranges. Numerous attempts were made to design a sludge pump incorporating the good features of both the plunger pump and centrifugal pump. In this direction the best answer today is the sludge pump conceived by the late Walter A. Bell while Plant Superintendent of the Northside Treatment Plant, Chicago, Illinois. This sludge pump is a modification of the centrifugal pump and is known today as the "scru-peller" sludge pump. This pump, however, has the inherent priming weakness of the centrifugal pump. This objection is overcome by the use of proper priming equipment. It has all the advantages of the centrifugal pump plus the ability to pass solids better than any other pump without clogging. Although the pump was designed for handling sludges, it has been used successfully at Army posts since 1934 for pumping raw, unscreened sewages.

The "scru-peller" pump has a two-screw conveyor which gives positive feed to a two-port impeller, thus eliminating the danger of partial sludge dewatering at the suction eye of the impeller. Cutting devices are provided in the conveyor housing to cut rags and other material into sizes that will pass through the pump. Cutting devices are also provided on the back of the impeller to prevent packing at this point. The suction nozzle is at right angles to the conveyor to prevent a whirling motion in the suction line. Bearing supports are provided at each end of the pump, as in plunger pump design, to absorb the shock imposed by the cutting load. If only one bearing was provided, the cutting load and uneven sludge concentration would impose too severe a load and strain on the bearing and shaft. Likewise, a two-port impeller is provided instead of a single vane impeller, because it would be impossible to balance a single vane hydraulically. The changing consistency of the sludge would cause undue vibration and whipping of the shaft. The operation of this pump is quiet. It is clean, because packing troubles are corrected in the design features. Having no valves, it is free from clogging and other ball and flap valve troubles.

The Sludge Piping System

Now that we have covered the advantages and disadvantages of sludge pumps, let us consider the factors that a well-designed sludge pipe system should incorporate:

1—A positive suction head is more desirable than a suction lift, regardless of the type of sludge pump used. Positive suction heads will minimize the difficulty of moving heavy sludges at the beginning of the pumping period.

2—The suction line should be as short as possible. The pipe

line should be entirely horizontal or slope towards the pump or rise vertically and then horizontally into the pump. The suction line at the point entering the pump should never be lower than any other point on the suction line. (See sketch.)

3—The number of bends should be at a minimum. Elbows and tees should have long radius bends to minimize stoppage.

4—The suction inlet end should be located on the side of the sludge well to prevent formation of a vortex and, as a result, prevent flow of air into the suction line. A suction inlet in the bottom of the sludge hoppers is likely to be clogged by tools dropped into the hopper.

5—Foot valves, float valves and check valves should never be used on the suction side of the pump.

6—A combination vacuum and pressure gauge should be provided on the suction side, and a pressure gauge on the discharge side of the pump. These gauges will indicate if clogging troubles are on the suction or discharge side and will indicate a build up in pumping head that may be taking place due to sludge caking (sludge ring) in the pipe lines.

7—The check valves on the discharge side of the pump should be placed near the top of the vertical run or, preferably, in the horizontal section if possible. (See sketch.) The position of the valve should be such that when the pump is shut down undue amounts of grit and other foreign material in the sludge will not settle and pack on top of the flapper and prevent the check from opening when pumping is again started.

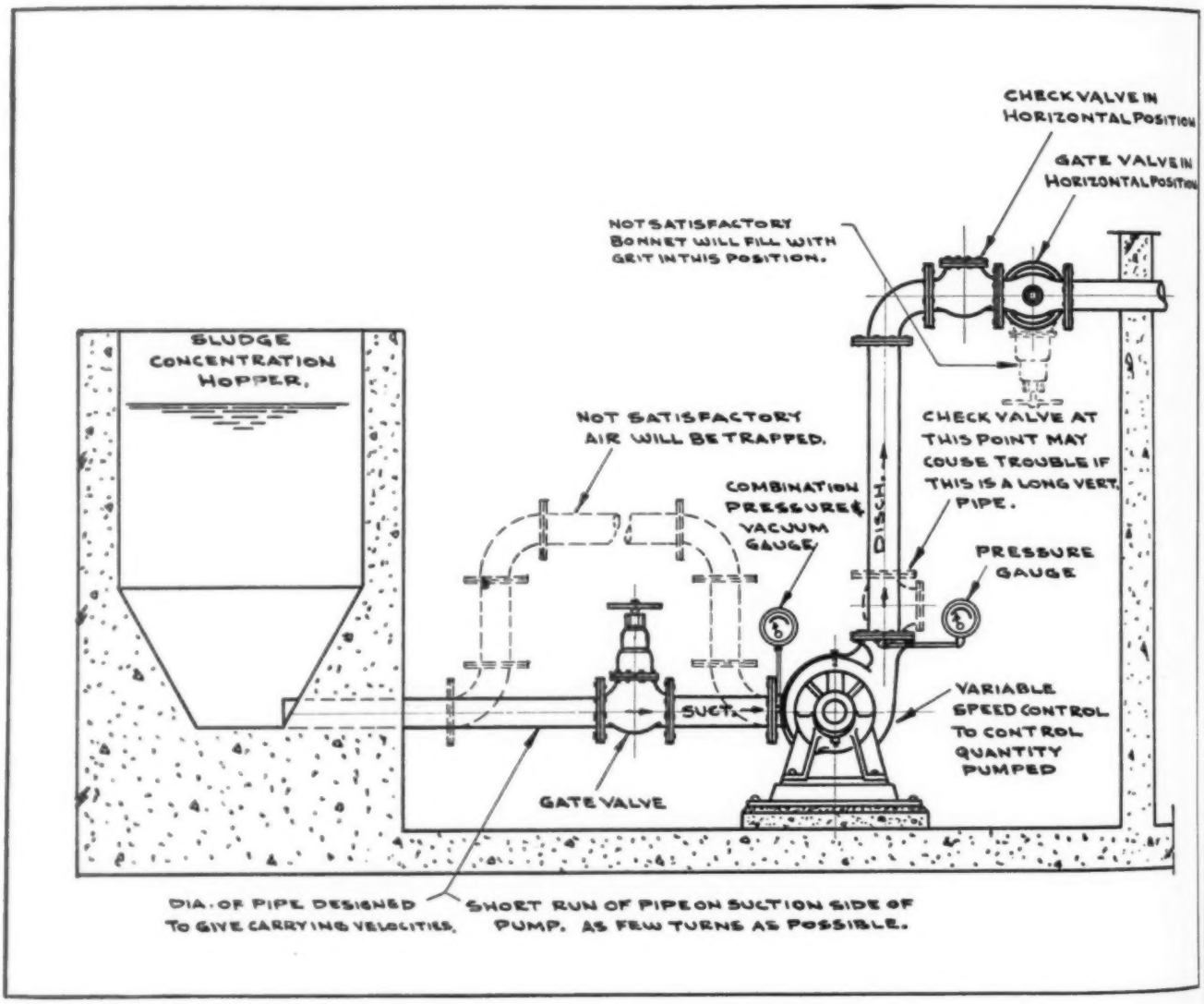
8—Pipe sizes on the suction and discharge side of the pump should be selected to assure scouring velocities (not less than 1 f.p.s.) in the sludge lines. Self-cleaning velocities will prevent or minimize sludge caking on the inside of the pipe. If the sludge line is too large to give cleansing velocities, the sludge will cake on the inside of the pipe line. In time this sludge cake will slough off and in all probabilities clog the line if not the pump.

It is difficult to understand why most of the sludge lines now in use, where the sludge is pumped, were not designed to fit the pump capacity and also give cleansing velocities. We would not think of designing a sewer with a velocity less than 2 f.p.s., even though the solids content is only 0.1 per cent. Yet sludge lines are built with velocities less than 0.5 f.p.s., handling concentrated solids as high as 6 per cent or more.

On a gravity system, or the sludge withdrawal system of Imhoff tanks, there is generally little trouble in the use of large sludge pipe lines, because normally the sludge lines are short and adequate head is available so that full opening of the gate valve will give high scouring velocities. But on a pumping system, the capacity of the pump and size of the sludge line will govern the velocity in the pipe.

In referring to the hydraulic tables it will be noted that in order to get a minimum velocity of 1 f.p.s., the approximate pump capacity for a 4-inch line should be 40 g.p.m.; for a 6-inch pipe, 90 g.p.m.; for an 8-inch pipe, 160 g.p.m.; and twice as much if a velocity of 2 f.p.s. is required. Slow velocities will also cause the heavier material to roll along the bottom of the pipe line. One can picture this rolling action enmeshing hair, rags and stringy material in the sludges and forming wads that may clog the pipe line or valves on the plunger pump.

Arguments generally presented are that 6 inch, 8 inch, and 10 inch sludge pipes must be used to pass the concentrated material and prevent clogging. The fallacy of this argument is that it


CHECK VALVE IN HORIZONTAL POSITION
GATE VALVE IN HORIZONTAL POSITION
NOT SATISFACTORY BONNET WILL FILL WITH GRIT IN THIS POSITION.
SLUDGE CONCENTRATION HOPPER.
NOT SATISFACTORY AIR WILL BE TRAPPED.
CHECK VALVE AT THIS POINT MAY COUSE TROUBLE IF THIS IS A LONG VERT. PIPE.
COMBINATION PRESSURE & VACUUM GAUGE
DISCH.
PRESSURE GAUGE
SUCT.
VARIABLE SPEED CONTROL TO CONTROL QUANTITY PUMPED
GATE VALVE
DIA. OF PIPE DESIGNED TO GIVE CARRYING VELOCITIES.
SHORT RUN OF PIPE ON SUCTION SIDE OF PUMP. AS FEW TURNS AS POSSIBLE.

Sketch Illustrating Some Good and Some Not-so-Good Features of Sludge Pump Installations
Installation of "Scru-peller" Sludge Pumps at Lebanon, Pa.

augments clogging troubles. If a plunger pump is used it is questionable if its ball valve chambers will pass a 1 inch sphere let alone a 5 inch or 6 inch sphere, and we know that match sticks will cause plunger pumps to lose their prime and cause a reduction in pump capacity due to slippage. If a "scru-peller pump" is used, whatever reaches the pump that is cuttable will be cut up and passed through the pump. Nevertheless, slow velocities cause sludge caking to build up on the inside of the pipe. In time this scum will break loose and plug the sludge lines usually at a bend, fitting, or valve.

Causes of Capacity Loss

Perhaps you have noted that the pump sometimes does not deliver its rated capacity. Let us analyze the reason for this condition: In the case of plunger pumps, the valves may have been worn to an extent that they cause too much slippage. Then again, sludges when subject to a suction lift or vacuum may release gasses to an extent that the pump may be pumping gobs of air followed by slugs of sludge.

We know that primary sludges have a varying degree of moisture. The moisture content in the sludge will generally be lowest at the beginning of the pumping cycle and will increase progressively to the end of the pumping cycle. During any cycle of pumping, the moisture content may vary from 90 per cent to 99 per cent. Sludges which have a moisture content of only 90 per cent will have a very high friction factor compared with sludges of 99 per cent moisture content. It is for this reason that during the first two or three minutes or more of any pumping cycle it is hard to get the sludge moving. The friction loss may be five to ten times greater than the friction loss during the balance of the pumping cycle.

It is generally easier to pump sludges having solids contents of less than 7 per cent. Above this point, depending on the character of the sludge, and particularly if it is around 10 per cent, you might have less trouble if you shovel it. Another point to remember is that sludges from one plant may be more difficult to pump than sludges from another plant, even though the solids content may be the same.

The unpredictable character of the sludge and its changing solids content has frustrated all attempts to establish accurate friction losses in sludge lines. As a result, it is more or less necessary to estimate the total dynamic pumping head. If you wish to increase or decrease the capacity of the pump, the simplest way is to equip the pump with a vari-drive type motor. Such a motor will allow you to increase or decrease the pump capacity by turning a small handwheel.

In speaking to operators where both plunger pumps and "scru-peller" pumps are installed side by side, it is surprising to hear the conflicting arguments that the plunger pump will pump heavier sludges better than the "scru-peller" pump and vice versa. Questioning fails to reveal any substantiating evidence. There is no reason why one pump should be able to pump heavier sludges than the other if both pumps are properly installed and in good operating condition.

Operating Problems—and Their Solution

You have often heard the remark that you should pump sludges at a slow rate to prevent pulling a hole in the sludge blanket. Also that a centrifugal pump will pull a hole in the sludge blanket whereas a plunger pump will not. Operators who made experiments and who took sludge soundings before and after pumping with both types of pumps know that this is not true. A hole might be pulled in the sludge blanket by any type of pump regardless of the pump capacity. The cause of this trouble is sludge arching, and failure to flow freely to the intake line.

The sludge may arch over the hoppers, around the sludge pipe in the hopper corners, or the hoppers may be too large with flat slopes and of improper design. Sometimes frequent pumping will prevent arching or the pulsating effect of the plunger pump will break part of it loose. The best answer is to squeegee, otherwise the breaking loose of the arched sludge may allow the gas bubbles to float the sludge blanket to the tank surface. If this should occur, hosing will make it settle readily.

Squeegeeing the hoppers will also reduce the pumping time on rectangular clarifiers, and it will reduce the amount of water formerly pumped to the digester. The less water pumped to the digester, the smaller will be your supernatant disposal problem. Another good way to minimize your supernatant problem is to draw the sludge into a concentration tank. After an adequate settling period decant the clarified liquor and then pump the concentrated sludge. If the sludge mixture is allowed to stay in the concentration tank too long without any stirring, you may find the supernatant on the bottom and the sludge floating on top. The best way to solve the supernatant problem is at the original source, in the undigested sludge, where the liquor does not have the toxic effect that it has when it leaves the digester.

Where plunger pumps pounded excessively, air snifter valves have been placed on the suction side to form an air cushion within the pump cylinder. This does a good job in overcoming pounding, but it is not recommended. Its evil is that you are sitting on a potential volcano that might go off any minute because while you eliminate pounding, you are also pumping a certain amount of the air with the sludge into the digester, making possible an explosive mixture.

Perhaps you have been faced with the problem of prime failure. If it is a centrifugal pump with primer, check your priming equipment for leaky gaskets, sticky valves, or stuck floats. Also, make sure that seal water is flowing to the stuffing boxes. If it is a plunger pump, leaky packing might have to be replaced or tightened. Often the trouble may be a clogged line, or the suction pipe may be sheared off where it enters or leaves a wall.

Perhaps you are having trouble with a check valve at the foot of vertical riser pipe that is being clogged by grit and other material settling on top of the flapper. If the check valve cannot be relocated near the top of the vertical riser pipe or in a horizontal section, you may find that a clear water flushing connection on the suction side between the pump and gate valve of great help to you. By flushing the pipe line under pressure after each pumping you can force the grit and other material to a point where it will not cause any trouble. This flushing connection will also be a great help in case it is necessary to dismantle the pump or clean the ball or flap valves. It is much nicer to work on a pump full of clear water than sludge. It should be borne in mind that this flushing connection should be made in accordance with cross-connection requirements of the State Department of Health.

WATER SERVICE AND SEWER RENTS

The following interesting decision is reported by the Municipal Legal Information Service of the New York State Conference of Mayors and Other Municipal Officials:

"On October 11, 1940, the Court of Appeals, Richmond county, Ohio, held that the city of Mansfield had authority by ordinance and rules and regulations issued thereunder to shut off water at premises which are delinquent in their sewer rental payments. Pointing out that it is well settled that a city may shut off water for nonpayment of a delinquent water bill, the Court considers the direct question involved in this case of the power of a city to discontinue one service for failure to pay for another service, and holds that the sewer and water systems are so closely related as to be considered one transaction as the operation of the sewage system is dependent upon the water supply, therefore, it is reasonable to shut off water for nonpayment of a delinquent sewer rental bill. The court cites and relies upon the case of *Dodd* v. *City of Atlanta*, 113 S. E. 166, which reached the same decision as was reached in the instant case. *Gatton* v. *City of Mansfield*."

PENNSYLVANIA SALT MANUFACTURING COMPANY

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• LIQUID CHLORINE

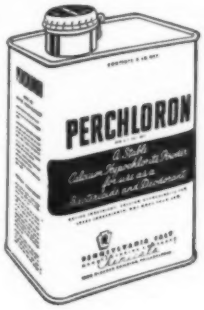
A clear amber-colored liquid about one and one-half times as heavy as water. Supplied in steel containers which are under pressure at temperatures above 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being about 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is about two and one-half times as heavy as air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.

Chlorine has been proved to be the most efficient, flexible and economical agent for sterilizing water supplies; and it is also used as a sludge stabilizer, a taste and odor eliminator, a precipitating aid, and, in sewage treatment, for disinfection, for B. O. D. reduction and odor control. The quantity of chlorine required in water purification and sewage treatment processes depends upon the quality of water, the point of application, and the object desired. Penn Salt Liquid Chlorine is particularly adapted for such processes because of its high purity and freedom from objectionable "taffy" or chlorine gum, achieved by means of the specially designed Penn Salt fractionating column which eliminates practically all harmful impurities from the chlorine.

This Liquid Chlorine is supplied in seamless steel cylinders of 100 and 150-lb. net. They comply with requirements of the Interstate Commerce Commission concerning specifications, retesting, loading, maintenance. Liquid Chlorine is also shipped in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes, 32,000 and 60,000-lb. respectively. The care with which all Pennsylvania Salt packages are cleaned and double-checked, coupled with the quality of Penn Salt Liquid Chlorine, assure maximum safety and convenience in chlorinator operation.

• PERCHLORON

Per*chlor*on is a high strength calcium hypochlorite, having a guaranteed active ingredient of not less than 70% calcium hypochlorite or available chlorine. It is free flowing, concentrated and retains its labeled strength for one year or more under normal storage conditions. It weighs approximately 52.5 pounds per cubic foot. It is composed of finely divided particles, all of which will pass a 20 mesh screen. It is quickly soluble in water, and is useful as a second line of defense for water purification in cases of emergency, when supplies of liquid chlorine may be temporarily cut off. Per*chlor*on is also used for sterilizing new mains, as well as clear wells and filters; valuable for sewage treatment, too. Many leading swim-



ming pools sanitize their water with Perchloron, use it to combat slime and algae growths, and to control athlete's foot by means of foot baths and by spraying locker and washrooms. Perchloron is supplied in 5-lb. cans, 9 cans to the case. Also in 100-lb. drums.

• AMMONIA, Anhydrous

A colorless liquid which at 70° F. is 0.61 times as heavy as water, and weighs 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F., 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

This characteristic of ammonia is utilized in the dry feed ammoniators in water works. It is also useful in the chloramine process, in which ammonia is applied along with chlorine to prevent the formation of chlorinous, phenolic or medicinal tastes; and for stabilizing or prolonging the sterilizing action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, with points of application ranging over the entire purification process. To prevent taste intensification, the ammonia must be applied before the chlorine.

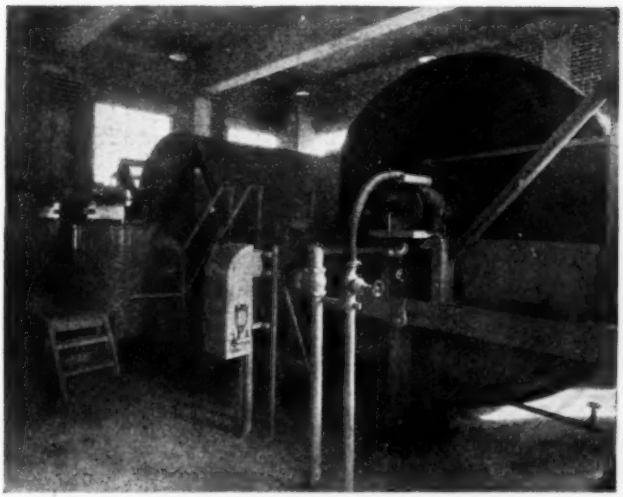
Pennsylvania Salt Anhydrous Ammonia is supplied in special improved cylinders of seamless drawn steel which are light, strong and easy to handle and store. Gas may be withdrawn either with a cylinder standing upright on a scale for weighing, or with the cylinder lying horizontal, whichever is most convenient.

• FILTER ALUM (Sulphate of Alumina)

This product is the principal coagulant used in water purification; and Penn Salt, Commercial or Iron Free Alum has been adopted by many water works superintendents and engineers. Available in any quantity from a single bag to carload lots.

• FERRIC CHLORIDE

In liquid form it is an aqueous solution, the concentration of which is governed by the outside temperature and varies from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Pennsylvania Salt also supplies ferric chloride in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as is permitted by impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most communities, depending upon shipping costs, ferric chloride offers vast savings over alum. The aqueous solution is shipped in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. Anhydrous ferric chloride is shipped in non-returnable steel drums, 150 and 400 lb. sizes.



• SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda, used both for softening water and as a combined coagulant and softener. Most effective in water requiring an alkali with the alum. Shipped in steel non-returnable drums, net weight 100 and 400 lb. each; and in 100-lb. moisture-proof burlap bags.

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CHLORIDE OF LIME, and
CAUSTIC SODA

are among the other chemicals made by Pennsylvania Salt and used in water purification and sewage treatment. Ask us for detailed information and expert technical assistance.

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Manufacturers of Chlorine and Ammonia Control Apparatus,
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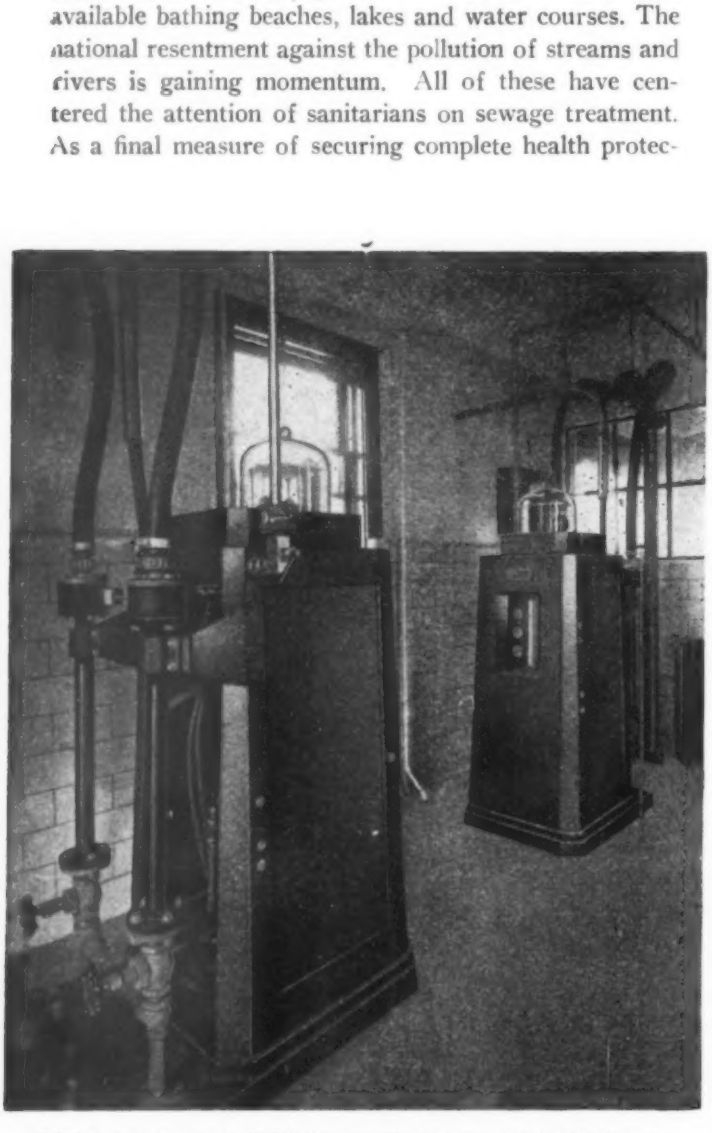
DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



W&T Master Automatic Visible Vacuum Chlorinators. Stamford, Connecticut, Sewage Treatment Plant.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any specific sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.

ACTIVATED SLUDGE BULKING*

Some Considerations as to Causes and Corrective Measures

By L. H. ENSLOW

Editor, "Water & Sewage Works"

In presenting this informal discussion, and my own opinions with regard to causes of bulking of activated sludge, I shall also offer suggested corrective measures for bulking. The matter of "sticking my neck out," so to speak, gives me little concern if, by such willingness to expose myself, I can provoke more consideration and study of this most vexing and important problem of operation. And, in my belief, of plant design also.

What Constitutes Bulking?

The first question is—"What constitutes bulking?" When I first entered the sewage field I had heard of bulking sludge but I had no idea what it looked like. I thereafter discovered that there was more than one type of bulking. These types, in my opinion, represent two entirely different causes and effects. One is peptization of sludge floc and the other is really bulking (swelling) of sludge. True bulking of sludge means that the particles have become hydrophyllic. This means that they have taken up water, such as leather will, and swelled to the point that the gravity is so low as to cause the bulked sludge to rise in the final clarifying tanks. When in this condition, slight disturbance and increased velocities will cause it to pass out over the weirs of such sedimentation units. If you examine this sludge closely, you will likely also find that the particles are buoyed up by myriads of tiny gas balloons; i. e. very small gas bubbles of microscopic size. To cite an example, I have observed that salt water oysters subjected to fresh water will exhibit this same hydrophyllic phenomenon of absorbing water. One may say that, like the oyster, the sludge has become "bloated."

Let us consider some of the qualities and characteristics of an activated sludge beginning to bulk. Under the microscope you find that amongst the sludge organisms the protozoa have become sluggish. Instead of working vigorously, (for instance, the stems of bacticella and the like no longer coiling and coming back with a snap as they do when in a healthy condition) you will find that they are lazy and not at their job of assimilating bacteria and what not. I do not know whether they do assimilate anything other than bacteria, but at least they are not active when the sludge is ailing or, is it a case of "vice-versa."

Following this you begin to get peptization or bulking, as the case may be. Bacteria increase, and there is an oxygen deficiency. Nitrates are going down, whereas ammonia is increasing. There is a loss of characteristic brownish color of good activated sludge. In due time the effluent begins to take on the odor of hippuric acid ("hippo" meaning horse). However, the effluent is splendid for a time after bulking of the sludge begins to appear. It is crystalline clear for a while and represents a very excellent effluent. If one could "put the brakes on" at this point and hold the condition, he would have optimum activated sludge operation from an economy standpoint, and as high an efficiency as he could expect. However, the difficulty is that he cannot easily stop the bulking-ball that has started rolling.

The next thing that happens is that the bulking becomes very pronounced. With increase in sewage flow, the sludge blanket is disturbed, and much sludge goes over the weirs into the stream. The liquid portion of the effluent, even yet, is not bad but becomes so in time, if the cause of bulking is not corrected.

What Causes Bulking?

Now let us consider some of the causes of real bulking (swelling), as distinguished from peptization of flocs and milky effluent, such as poisoning of bacteria as enzymes may produce. The universal answer is the deficiency of dissolved oxygen reserve and nitrates in the aerating units or in the final settling tank. The latter may be as important as the former. In other words, the way I look at it, the problem becomes a question of oxygen "banking." Picture an aeration tank (sketched on the black board). Whether by air diffusion mechanically or by air blowing, in the aeration tank liquor you are "banking" dissolved oxygen. With this banked oxygen you can meet demand notes by withdrawing or checking. The notes are the oxygen demand "notes" of the sewage plus that of the sludge in the mixed liquor. If your balance is steady, or on the increase, and your withdrawals are gradually on the decrease through the aerators, you will always have at all points in your "oxygen bank" a residue of dissolved oxygen on which you may draw. Such means solvency and will keep you from going absolutely oxygen bankrupt. Assuming this condition can be maintained, you will never find yourself "in the red"—at least as to performance if not in respect to costs. If you do overdraw your oxygen account but within an hour or so you replace the overdraft, adding perhaps a little surplus, you are still safe from your principal debtor whose initials are B.O.D. In commerce the criterion, of course, is how quickly and adequately you are able to do your banking, that is, how quickly you can make your deposits to meet the on-coming drafts or checks. Just so it is with the balance between oxygen reserve and oxygen demand in an aeration unit, which spells solvency, or bulking bankruptcy.

Another analogy may be made in citing two runners—one a strong runner and one a weak runner. Should the strong runner stub his toe just as he takes off from the starting point, he may have a hard time to overcome the set-back and may even come in, a limping loser. Overcoming such a handicap, even against weak competition, is frequently very difficult. So it is in financing, that is, in making up bank deficiencies; and, so it is in the activated sludge process in making up oxygen deficiencies which reach serious proportions near the influent end of the aeration units.

The rapid oxygen demand of the sewage, as I stated, is the critical thing. This occurs at the inlet end of the aeration unit and represents the sudden demand notes drawn on the oxygen in the bank. I have seen activated sludge plants operating very nicely on very strong sewages, as long as the input remained on an even keel. On the other hand, I have seen activated sludge plants confronted suddenly with varying organic loads, and the process has gone all to pieces with startling rapidity. One would not think that these periodic loadings could disrupt the process the way they do. Of course, what I have said is particularly true of small plants. In large plants it takes much more to cause trouble than in smaller ones, for the reason that your bank is stronger and the "balance" is not so easily upset.

Sludge vs. Liquor.

Too much sludge carried in the aeration tank has an effect similar to too much of an organic load in the sewage coming in. However, in my opinion, the sludge loading does not begin to compare with the influent loading in importance. The reason is that it is a more stable load and is subject to control. It is not flashy unless somebody permits the sludge to become partially septic; then, of course, it has an explosive oxygen demand which is disastrous. The return of supernatant liquor from digesters is a tremendously bankrupting practice as many have learned. More about this later.

Another cause, I think, of activated sludge bulking or perhaps of moderate bulking is a lack of inorganic matter in the sewage. I refer now to material like iron, salts, silt or clay, and other materials which tend to give weight and coalescence to floc of any sort, whether activated or not. As a matter of fact, I consider the activated sludge process to be as much of a natural coagulation process as it is of an oxidation process. The first stages of coagulation and adsorption are by far the most important stages in activated sludge, and if we could chop it off at some point before nitrification sets in (and hold it there) we would have the greatest amount of work for the least number of dollars for operation. Unfortunately, no one has found the formula for this procedure, the nearest to it being the Guggenheim biochemical process which involves a combination of chemical precipitation and bioflocculation.

I might mention that recently there has been considerable work done on the use of silica as a coagulation aid. Perhaps many of you have heard that in water treatment practice silicates may be

**A paper presented before the Ohio Conference on Sewage Treatment; reprinted from the 12th Annual Report of the Ohio Conference.*

used for improving flocculation with alum and iron, and so in sewage treatment it may well be that something of this nature will be found to play a part in activated sludge coagulation. I cite one indication that silica may have a distinctive bearing. I have frequently observed cases where clay or silt enters sewers as a result of rainstorms. And, almost immediately the coagulation phenomena of activated sludge, the settleability of the sludge, and consequently the important sludge index, seem to improve. I am wondering if perhaps the colloidal silica content of clays may not have a bearing on activated sludge coagulation as it does on alum and iron coagulation. I consider this an interesting problem for some student or researcher to undertake; namely—"The Effect of Various Inorganic Compounds on Activated Sludge Behavior."

Another reason for the bulking of sludge is too little oxygen input in the sludge reaeration channels, if reaeration is practiced. In other words, your bank balance is decreasing rapidly and can decrease extremely fast if you do not keep well ahead of the sludge demand, so to speak. Sludge may have (and frequently does have) a rapid oxygen demand as it comes from the final tanks. In other words, if you are returning your sludge slowly to obtain a concentrated return, you are tending to build up in that sludge an increased and a rapid oxygen demand. Should you not have enough oxygen to take care of the demand immediately, and not enough carrier liquor in which to "bank" this oxygen, you will never catch up. By putting into the inlet of the aeration unit an oxygen deficient sludge you have lost ground before the mixed liquor enters the aeration tank and, in my opinion, that is the reason for the difference in arguments, pro and con, for reaeration of sludge. A new theory is that reaerated sludge must be kept nourished with fresh sewage input. Some will tell you that reaeration is worthless and that it is really harmful, whereas others say that they cannot get along without it. I believe it to be just a matter of the balance of oxygen reserve as to whether or not an operator needs or does not need reaeration of sludge. The British practice is to reaerate and return very thin sludge. The freshness and thinness of their sludges may account for their successes with reaeration.

Another point is the ratio of settleable solids to non-settleable solids in the sewage. I mention this point for the following reason. In Great Britain one of the remedies in sludge bulking is to by-pass the long period primary tanks, thus diverting more suspended solids into the aeration units and also securing a fresher sewage, with benefits later to be cited.

Grease and oil have an effect on sludge bulking. Grease or oil mix in with the activated sludge floc and coat the particles, affecting the specific gravity of the sludge if nothing else. Many engineers think it has considerable bearing on the bio-activity of the sludge. Studies now under way will tell us more about this later, but grease separation appears definitely beneficial.

There has been a suggestion that yeast is harmful and results in bulking; that is, yeast from breweries and other places. Some British authorities seem to think yeast is very harmful. I think possibly the yeast growth is the index of something else that is worse. I refer to the oxygen demand, and more particularly to the demand rate of the waste which contains the yeast; but this again is a personal opinion and needs verification. Where yeast is, there is usually a lot of organic matter with it.

Then we come to filamentous bacterial growths, of which we hear so much, such as sphaerotilus and leptothrix. In paper mills they call these growths "slime." I will speak a little more about filamentous growths later. They may be the cause of bulking, but I do not believe they are the direct cause. I think they are indexes, again, of a deficiency of oxygen which is the direct cause of bulking.

Then, of course, there is carbon dioxide. Gas liberation, carbonaceous fermentation and acid production unquestionably have an effect on bulking. Septic sewage and supernatant digester liquor, in my opinion, is probably one of the most serious factors contributing to bulking in the greatest number of plants.

The Effect of Septic Sewage.

I was very much interested in an article that appeared in the July, 1938, issue of "Water Works and Sewerage." Written by Dr. Heukelekian, of the New Jersey Experimental Station, it more or less fights this battle for for me. I have claimed a lot of things that were bad of septic sewage, but I did not know what the New Jersey authorities have revealed—namely, "That once sewage has become septic it will take up oxygen only one-half as fast (approximately) as the same sewage in a fresh condition." In this revelation many will be surprised and take on an increased respect for septic sewage and supernatant liquor. In his studies of the effect of septic sewage on activated sludge, Dr. Heukelekian took septic sewage, boiled it to kill all life and then reaerated it. He found that the same sewage in a fresh condition, treated in the same way, would take up twice the oxygen; that is, would take the oxygen at twice the *rate*, the latter being the important revelation. The amount of oxygen required is not nearly so important as is the rate at which it is required, and the *rate* at which it will be dissolved and "banked" in the liquid phase.

With the above in mind, septic sewage reaching a plant in hot weather reduces the capacity of the storage reservoir of dissolved oxygen by about fifty per cent. For instance, Dr. Heukelekian found that in twenty minutes of aeration, fresh sewage (boiled) would take up 3 parts per million of oxygen (approximately) as against 1.8 parts per million for *septic* sewage treated in the same way. You will note that this is almost two to one. But this is not the whole answer. The important consideration is, that if this happens every twenty minutes from the influent end of the aeration tank through the effluent end of the tank, and if the aeration period is six hours, the effect is considerably multiplied, and interest on the deficit is compounded. Let us put it this way. The dissolved oxygen "balance" is in pretty bad shape before you get to the end of the tank. You have not accumulated anything, because the oxygen is going out at a rate you cannot control, and this rate is faster than it can be deposited. This constitutes about the most interesting disclosure I have seen in the way of an explanation of why it is desirable and many times necessary to avoid septic sewage. We do know that in hot dry weather more than one activated sludge plant operator goes home at night and prays for rain. When he gets rain he knows he is on safe ground, at least temporarily. In my opinion, dilution is one of the best corrections for septic conditions, and it is not a far cry to recommend that a handy creek be bled into a sluggish sewer in hot dry periods.

Supernatant liquor from digestion tanks, if discharged to the inlet of the plant, causes an effect similar to septic sewage, but there is so little of it that you do not begin to feel the cumulative effect that you would if all of the sewage is septic. However, the fact is that supernatant liquor does cause serious upsets of the process. Further, it probably encourages the growth of organisms in the sewage which I believe those of normal activated sludge do not like as associates, and likewise adds toxins.

Peptization of floc can be caused by different things, but you usually find that this condition is caused by a poison of the decolloidizing elements or organisms in the sewage and sludge. In other words, the clotting effect is hurt and you do not get efficient flocculation. Peptization results in a whitish milky-looking effluent.

Correctives

Now consideration may be given to possible correctives and there are several of them. Some of them work and some do not. Some work here; some work there; and some work nowhere. The first thing to try is more air—if you have it. The next thing is lesser amounts of return sludge, reducing the amount of solids in the sludge rather than the volume. If anything, you usually have to increase the volume of return sludge. The third measure, of course, is less sewage. That last seems to be a universal corrective because by-passing has been the most prevalent method of correcting difficulties at activated sludge plants. Adding clay is another method and the use of chlorine still another.

I was extremely interested in another phase of Dr. Heukelekian's paper. His conclusion reads, "The dissolved oxygen level in the activated sludge process is the resultant of the supply and demand of oxygen. The supply is governed by the method and rate of aeration available." Further quoting from his conclusion he says, "Another factor that influences the level of dissolved oxygen is the temperature. As the temperature increases, the amount of oxygen that can be dissolved in the liquor decreases, and at the same time a greater demand exists due to increased biological activity. Thus, the critical periods in the operation of an activated sludge plant appear in the warmer season." If you add to this condition septic sewage, the operator's difficulties are further increased. On both scores the mixed liquor naturally will not dissolve as much oxygen.

Again quoting, "Theriault and McNamee have estimated that 35 per cent of the dried activated sludge is represented by bacterial cells. * * * The bearing of these generalizations on the maintenance of dissolved oxygen in the activated sludge process is obvious. As long as aerobic conditions are maintained, the process of aggregation of sewage colloids will take place, resulting in a well clarified effluent and an active sludge. When there is no dissolved oxygen present the process of aggregation will cease, the opposite process of dissolution will take place, breaking up the aggregated sludge floc."

Dr. Heukelekian then concludes by saying, "Until more definite information is available, indicating that with higher dissolved oxygen concentration a much more rapid purification is brought about, a minimum of 0.5—1.0 p.p.m. dissolved oxygen maintained at all times and in all sections of the aeration tank should be considered as the most economical range."

Other correctives have been seasonal treatment of industrial waste to reduce the load on the plant. Lime have been employed for pH correction, but I will say that my experience has been that the use of lime offers very temporary relief. It does seem to shrink the sludge temporarily, but you soon find that the effluent becomes milky and conditions become unsatisfactory again.

Other methods than by-passing include reaeration, more rapid sludge return, which I have touched on, thickening of excess activated sludge going to the digesters, and stage digestion of sludge, which gives a less objectionable supernatant liquor.

Sludge Thickening.

As to sludge thickening, it was first developed at Los Angeles and later used at Phoenix, Arizona, where it proved a "life-saver." Topeka practices it as does Columbus, and Baltimore is including it in the design of improved works. When sludge thickening is practiced, the sludge is not returned to the raw sewage for settling in the primary tanks where it may become degraded and much of it passes over into the aeration tanks. To my mind, it is extremely questionable practice in activated sludge treatment, and poor economy to return this material to the sedimentation units. A good many people have argued contrary to this, but I have observed many activated sludge plants, have studied them, and have thought about them a lot. When I see this bulky, half-rotten sludge which was put into the tanks as good activated sludge, which laid on the bottom as long as it could and which finally is swept through to the aeration units, I am certain it has a tremendous oxygen demand. It has a tremendous chlorine demand and anything that has a tremendous chlorine demand likewise has a very high oxygen demand. I do not know whether the organisms contained have any effect on the aeration tanks or not, but I do feel that the needless load on an activated sludge plant, caused by this manner of handling sludge, is absolutely unnecessary. It is necessary to take all the load coming to the plant (the sewage) but why should you take a good activated sludge and let it go through partial digestion and put it back into the aerating tanks again during periods of peak loadings?

"Freshening."

Sewer flushing or sewer dilution has always been helpful where septic sewage is the cause of the trouble. I have often said that any operator is fortunate who has the trunk sewer to his plant passing under a brook or stream. By knocking a hole in the sewer and by fitting it with a suitably constructed valve, he is able to realize the value of sewage "freshening" and sweeping sewer flows. It may even pay to install pumping equipment and pump water from a stream, or he might even pump some plant effluent back into the incoming sewage. In my opinion, it may cost less to pump water into the sewer than it does to pump air for aeration purposes and there is little question but that the operator will sleep better at night.

Sludge Return Control.

Now, about sludge return reduction. This seems to be an extremely important item at times. First, the operator keeps down his solids and, second, he draws his activated sludge back fast enough so that he gets more fresh liquid to dissolve more oxygen in the "banking" process. Many of you may be surprised to know that at some plants the return sludge is 50 per cent to 100 per cent by volume. Now why do the operators do this? It is more or less for the same reason that I would like to have a creek pass over the trunk sewer to any activated sludge plant which I would have to operate. The increased return sludge volume naturally will reduce the aeration period, but a 6-hour aeration period does not necessarily mean a thing in the world. One may get better results in two and one-half hours if he knows how. More liquid is delivered to the aeration units, thereby supplying a "blotter" tnat will absorb more oxygen and hold that oxygen in a higher concentration (probably three times as much) than is possible with strong or septic sewage. Naturally, the total oxygen demand is the same but the operator has been able to put more "money" in the bank. While the total draft remains the same, he avoids oxygen bankruptcy. The whole point is this: Put something into the aeration tanks that will dissolve the oxygen input and then furnish the tank with all the oxygen (air) you have.

There are some operators who say that they want to have a "sludge reserve" for return at augmented rates when troubles appear. Well, all I have to say is this: They are just inviting a lot of trouble. It is ideal (on paper) to have a big reserve sludge tank that can be kept thoroughly activated all the time from which the so-called "shock troops" may be obtained. I know one plant (London, Ontario) working on this basis, but it costs the municipality a lot of money. Actually what those fellows do in London is to return super-aerated sludge to the sewage in the aeration tank. This aerated sludge acts rapidly. When I heard of the theory of zeolite action by sludge, I thought right away about the London scheme, because the operation at this plant is probably as good an example of such action as anything I have seen. Sludge is reaerated for about twelve hours. The contact with the sewage is less than two hours. There is no question but that a good plant effluent results, but the power requirement certainly reflects the high cost of sludge reaeration. And, every so often something has to be done to retard the activity of sludge in the reaeration stage.

Chlorination.

Now this discussion has developed to the point at which I will refer to chlorination and its uses pertinent to activated sludge. First, considerable can be accomplished by chlorinating up-sewer to suppress septic action in sewage. This has been demonstrated better perhaps in Los Angeles County than anywhere else. There it was impossible to treat more than about one-half the sewage flow until up-sewer chlorination was instituted. It was really remarkable how readily the sewage quality was modified and the entire flow could be handled once chlorination was established.

Then, there is return sludge chlorination, which was really "born" in Ohio, and credit goes to E. E. Smith of Lima and to M. W. Tatlock of Dayton for having initiated this procedure.

After Smith and Tatlock told us about chlorination of return sludge the next place at which we heard of its use was at Lancaster, Pennsylvania. I may say, that too much chlorine in the chlorination of return sludge results in peptization, and a "milky" effluent is an indication of such. However, return sludge chlorination certainly has possibilities, as has been demonstrated at other important plants. At Lancaster, aero-chlorination is now being used for grease separation and Mr. Weist, superintendent, has written me that he believes aero-chlorination is better for his purpose than return sludge chlorination, for the reason that it separates grease which previously he had found in his activated sludge. In other words, it is doing two jobs, so to speak.

Phoenix, Arizona, has been practicing concentration of waste sludge for some time, sending it directly to the digester and chlorinating the digester supernatant liquor for return to the aeration units. This has done a lot of good, but now, in addition to this practice, the Phoenix authorities have gone to chlorinating the return sludge.

Now why does this chlorination of return sludge work? I again wish to emphasize the fact that I advance *probable* reasons, largely personal opinions. First of all, bacterial control is accomplished, that is, control of the growth of saprophytic organisms, not the organisms we see on 37 degree plates but those that take up so much oxygen. In this group are the bacteria of fermentations and the sulphate splitters. They produce a lot of CO_2, a lot of hydrogen sulphide, and a lot of trouble for a lot of operators. I liken their presence or absence to cold weather versus hot weather conditions. In other words, if you can suppress bacterial activity through your aeration tanks, these organisms are not present to draw upon the oxygen and to dissipate it rapidly. There is less oxygen demand in the absence of these organisms. For one, I do not believe that saprophytic organisms, as a general rule (certainly not anaerobic organisms), have a place in a sewage plant, other than in the digestion tanks.

The second reason why chlorination of return sludge works is that control is had of filamentous growths. I frankly believe sphaerotilus and other slime forming organisms which we find in activated sludge (like pH and dissolved oxygen) furnish an index of conditions. I believe the deficiency of oxygenation is the real cause of bulking and that filamentous growths, since they will not grow unless a low oxygen balance is had. are principally an indication of a deficiency of oxygen. Chlorine suppresses the rate of dissolved oxygen disappearance and maintains the oxygen balance. In doing this, filamentous growths are controlled. I have seen these biological growths in streams below sewer outfalls, as many of you have, but they disappear just as soon as you begin to get to a stable or balanced oxygen condition. The activated sludge process, with controlled application of chlorine to return sludge, does not "stub its toe" at the inlet end of the aerators and, therefore, does not come limping down

to the finish line. This practice has accomplished much at Lima, Ohio; Phoenix, Arizona; and Houston, Texas. As a matter of fact, I believe that at Houston the greatest benefits of all have been accomplished by chlorination of the return sludge.

In this connection I will first read from a letter which I recently received from D. Travaini, superintendent, relative to an experience at Phoenix, Arizona. In part he says: "In April of this year we had a beautiful case of bulking. Our convention (Arizona Sewage Works Association) was three days off and we weren't happy with our results. The aerators were so full of filaments that the sludge had completely lost its identity. We ran an emergency chlorine line from our chlorinator to our reaerator and in five days our bulking was completely gone. One hundred pounds of chlorine per day did the trick. The chemical dosage (based on volume of sludge returned) amounted to 5 to 6 p.p.m. of chlorine. Since then we have played around with chlorinating our sludge. Our plant is up to design capacity, but in spite of this fact, by using 75 to 100 pounds of chlorine per day, we have been able to eliminate one aerator from service at a saving of about $50.00 per month, in favor of chlorine over power. We had a serious breakdown in the aerator in question so we had to follow the procedure mentioned but it worked, so we planned to continue this practice."

Houston, Texas, has for some years suffered with an overloaded activated sludge plant. Although at this time the plant is in the process of being enlarged, the boys down there are due a lot of credit for keeping the present plant on as even a keel as they have. I wish to read from a paper by William Pralle, assistant city engineer in charge of sewers, at Houston. This paper, which deals with the operation of the sewage treatment plant, was presented before the Texas Water Works Association. I quote from the paper as follows:

> "Another advantage of an activated sewage treatment plant is that with a little larger operating cost, from about $1.50 to $2.00 per M.G. according to the delivered cost of chemicals, the plant capacity can be increased without spending a young fortune for permanent construction of extensions.
>
> "To make myself clear, I do not mean to hold back on proper capacity to meet average daily flow of activated sludge plants, but do believe in having the plant equipped with a chemical unit to be used in emergencies, and at times when the plants appear to be overloaded.
>
> "The South Side Sewage Treatment Plant in Houston, employing the activated sludge process, has been increasingly overloaded in both aeration and sedimentation capacity for several years. The result has been that the general difficulty, commonly referred to as 'bulking,' was almost continuously present. In the Spring of 1937 a plan for experimentation was adopted, whereby chlorine and chlorinated copperas, or either one of these chemicals as found best by experience, was to be applied during the treatment process.
>
> "Chlorine alone has been applied to the returned sludge at Houston, just prior to mixing with the incoming raw sewage, since May 16, 1937, and the resulting improvement in the plant effluent has been very satisfactory.
>
> Only a portion of the data collected is in form for presentation here, but the following indicates the general improvement so far realized in the plant effluent.
>
> "The average 5-day B.O.D. of the plant effluent for four months prior to chlorine application was 66 p.p.m. and the filterable suspended solids 96 p.p.m. The average B.O.D. determined daily for the two weeks, May 16th to June 1st, was only 37 p.p.m., or almost half. And, the filterable suspended matter for the same period was likewise cut practically in half.
>
> "Chlorine was applied at the average rate of 5.34 p.p.m. to the returned sludge. At this particular plant the volume of returned sludge is, for operating reasons, much higher than is usually practiced in per cent of raw sewage treated. The average aeration time at this plant is practically 2½ hours, so that the reduction of the volume of returned sludge, made possible by chemical treatment, has produced part of the benefits.
>
> "During chlorine application microscopic examination made daily has shown a distinct reduction in number of filamentous organisms in the sludge. * * *
>
> "It has further been definitely found that effective control of chlorine application is necessary for best results, and that over-chlorination will produce undesirable conditions from which recovery is slow."

Then, in his letter referring to an operating record chart attached, Mr. Pralle replies to questions asked by me as follows:

> "You have referred to some of the shortcomings of the chlorine application, or conditioning of returned sludge. Excepting the added cost, the only comment we can offer at present is that a definite 'overdosage' is possible and should be guarded against. The limits of the amount which can be applied with benefit have not been determined, but our experience has shown that a very cloudy appearance of the effluent can be obtained and this has been relieved only by reduction in the chlorine quantities.
>
> "During construction incident to enlargement of our North Side Plant, chlorine application has been in progress for about 90 days. The data obtained are now being compiled, and these promise to given even more satisfactory information.
>
> "Questions of 'Cause and Result' have been found which have not been answered to our satisfaction, so that all comments are welcome. For instance, attention is directed to the greater difference between suspended solids and B.O.D. content of plant effluent during chlorination than prior to chlorine application. (Mr. Pralle is referring to the fact that B.O.D of the effluent improved more markedly than the suspended solids reduction would indicate.—Ed.) Our laboratory methods in all instances have been the same, and two questions are: (1) What has happened to the B.O.D. of those suspended solids which tests indicate are present in the effluent? (2) If the B.O.D. test of the effluent has been vitiated by this small amount of chlorine (as some seem to think is the case) why, then, is the B.O.D. reduction still evident in the analyses of water of the receiving stream below the plant?"

The reason I have read excerpts from Mr. Pralle's paper is to call attention to the fact that as long as the plant is performing better, the effluent is good, and the dissolved oxygen conditions downstream are good, an operator need not be concerned as to the exact technical explanation of the chlorine effect. However, it would be interesting to have more exact knowledge of the effects. This paper, with the accompanying analytical data, indicates that when you have difficulty in keeping your oxygen input up to a satisfactory level, it is a pretty good idea to return a thin sludge at higher rates, than a thicker sludge [longer removed from the aeration cycle) in lesser volume. The interesting thing with reference to the data at the Houston plant is what happened to the B.O.D. of the plant effluent when chlorination of the return sludge was stopped. As Mr. Pralle has stated, after the discontinuance of return sludge chlorination for a period of ten days, just about ten days with chlorination was required to get the plant back in a satisfactory condition. These results and Mr. Pralle's experiences at Houston strengthen my belief that there is a very tangible "something" to the chlorination of return sludge.

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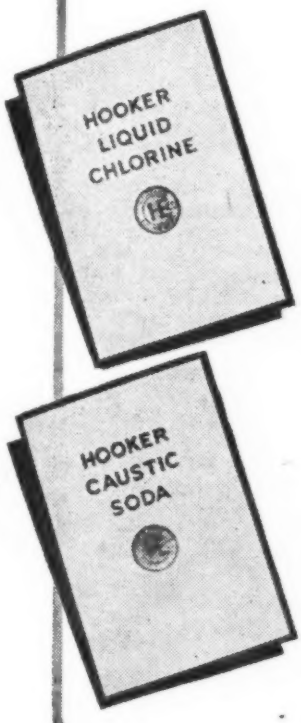

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SERVICING OF POROUS AIR DIFFUSERS

By FRANK C. ROE

Director of Sanitary Sales, The Carborundum Co., Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

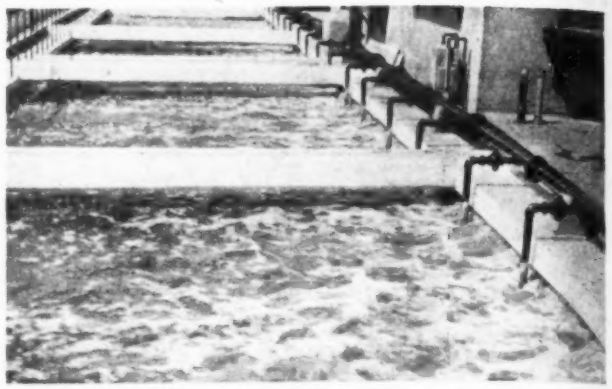

Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

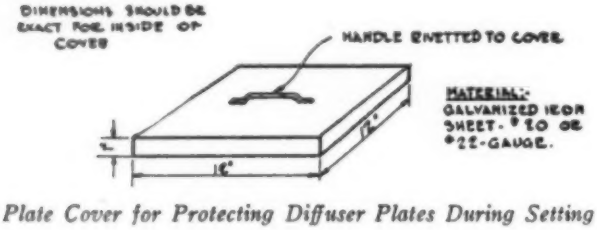

Plate Cover for Protecting Diffuser Plates During Setting

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used

[*For an excellent discussion of "The Economics of Cleaning Air-Diffusion Media" see the magazine section of this issue.*]

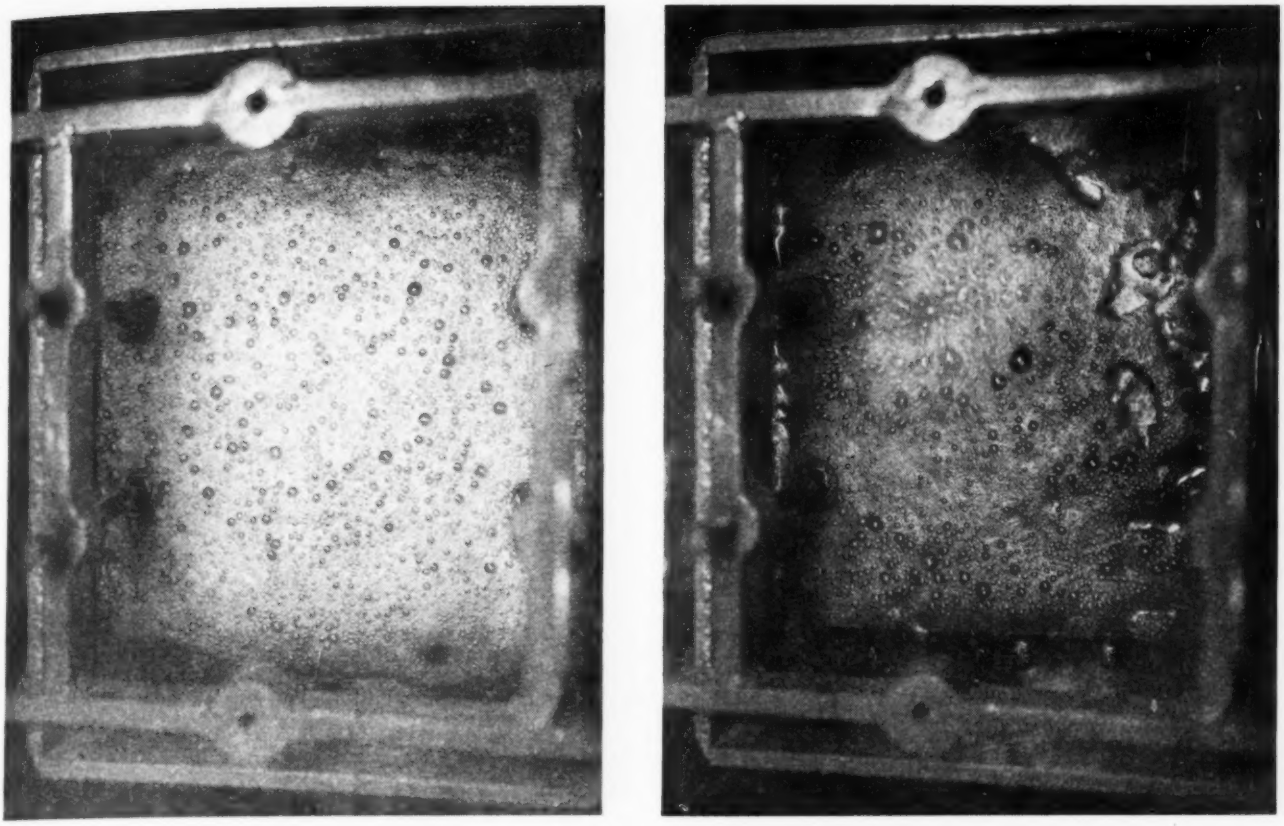

Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

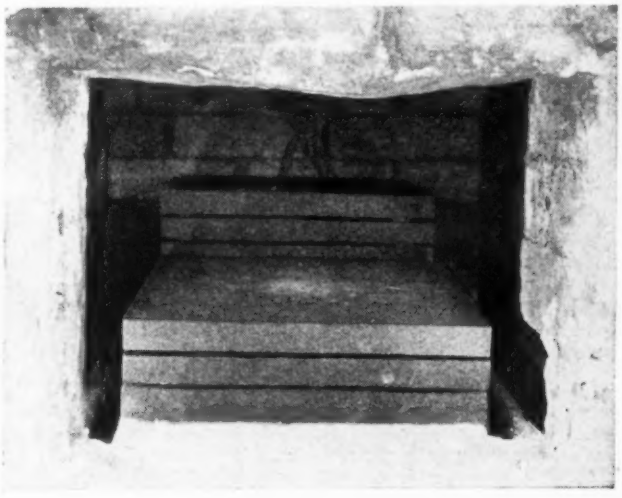

Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, *maintaining maximum air discharge during the operation.* One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: Dry plates by draining containers and blowing out porous structure with air at high rate. Apply oxy-acetylene flame with oxygen at 10 lbs. pressure and gas at 5 lbs. pressure. The flame should be applied almost parallel to the diffuser surface, i. e., at as acute an angle as possible. Remove from .010 in. to .015 in. of diffuser surface. Sweep off and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air side of diffusers.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ½ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants. In this connection the new "swing" diffuser and stationary diffuser equipment offered by the Chicago Pump Company is highly recommended.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

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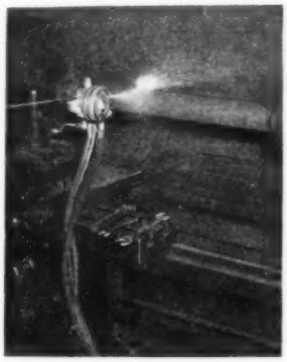
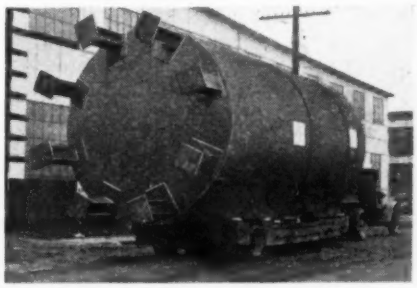
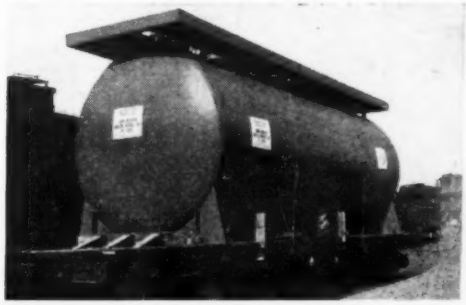
Metal spraying equipment of latest type, restoring worn bearing area.



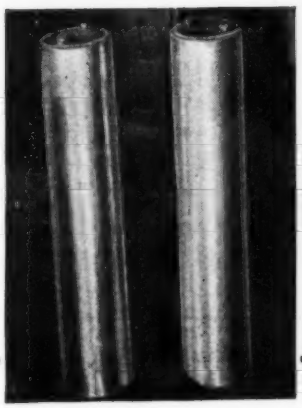


12'-0" x 25'-6" Steel storage tank of ASME welded construction.



Steel storage tank protected on interior with metal sprayed zinc.

Large chemical mixing tank of stainless steel.



Cast iron pump plungers restored to size with sprayed stainless steel.

Lining interior of storage tank with zinc by metal spraying.

NOOTER ST. LOUIS

PNEUMATIC GRIT WASHER AND EJECTOR

By NELSON M. FULLER

Superintendent, Water Works and Sewerage
Olean, N. Y.

THE removal of grit at the Olean Sewerage Treatment Plant is a very important detail of plant operation. Large quantities are received from storm drainage and from railroad repair shops. Also large amounts of sewage solids settle out in the grit chamber. Former methods of removal by hand, chain hoist and truck followed by burial were very disagreeable, being akin to cleaning out a large privy each week.

Formerly six man-days were required to carry out this operation, whereas the air lift system now in use washes the grit and disposes of it in thirty minutes. A mechanical conveyor system proposed for the removal of the grit would have cost $5,000. Using scrap materials and our own welders the air-lift pumping equipment herein described cost under $100.

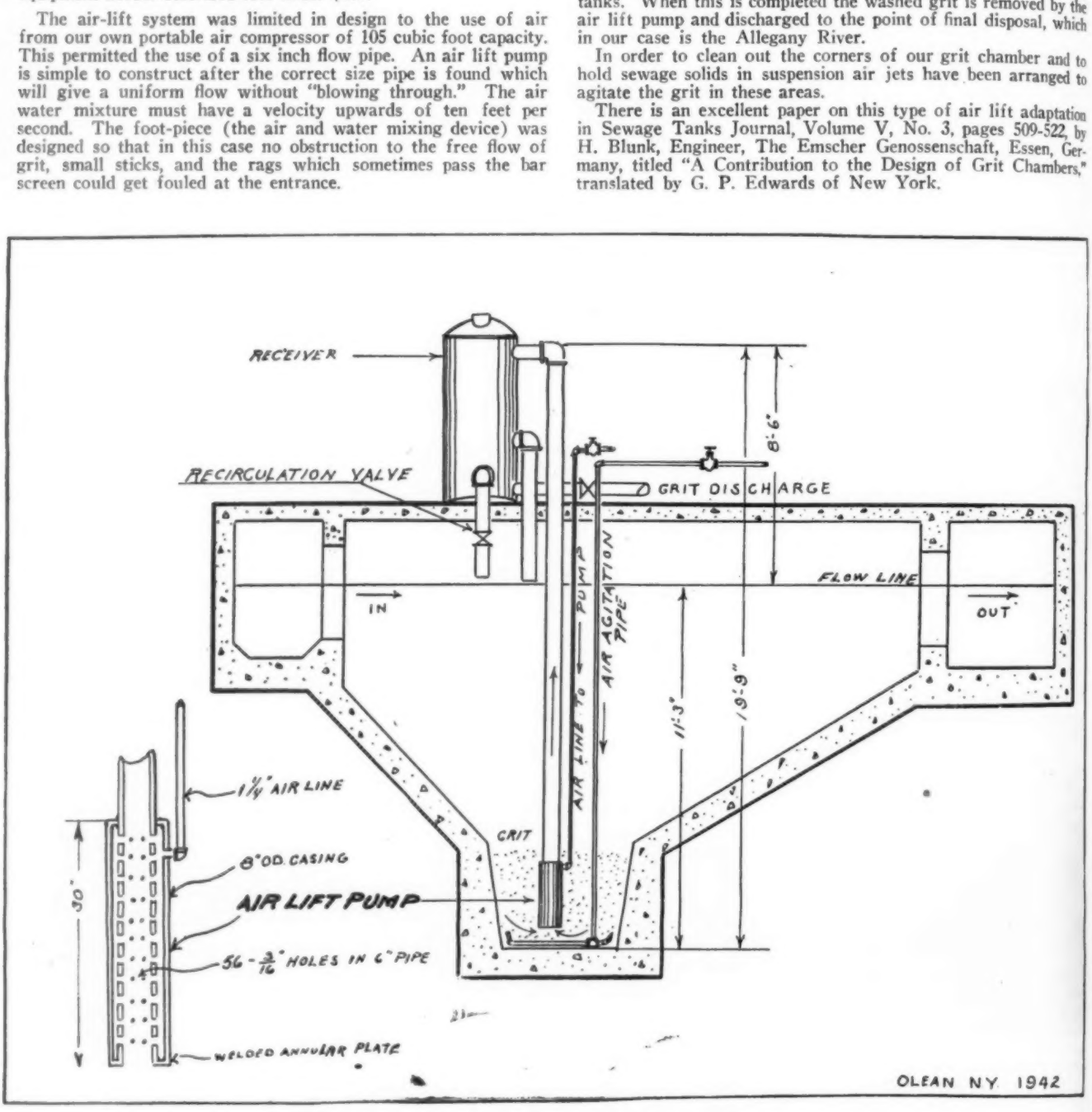
The air-lift system was limited in design to the use of air from our own portable air compressor of 105 cubic foot capacity. This permitted the use of a six inch flow pipe. An air lift pump is simple to construct after the correct size pipe is found which will give a uniform flow without "blowing through." The air water mixture must have a velocity upwards of ten feet per second. The foot-piece (the air and water mixing device) was designed so that in this case no obstruction to the free flow of grit, small sticks, and the rags which sometimes pass the bar screen could get fouled at the entrance.

The sketch accompanying this description shows a detail of the foot piece, which was made by boring fifty-six three-sixteenth holes in a thirty inch section of six inch pipe. This section of pipe was then placed into a piece of eight inch pipe and welded at both ends. The one and one-quarter inch air line was connected into the eight inch casing. A small tank was picked up as junk and was used for the air and water separator or receiver.

It will be observed from the sketch that the grit discharge line from the receiver can be closed and that the grit and solids can be recirculated to secure any desired period of washing action in the grit chamber proper. After a suitable period of washing the grit is allowed to settle and the sewage solids which are then in suspension in the grit chamber are flowed into the settling tanks. When this is completed the washed grit is removed by the air lift pump and discharged to the point of final disposal, which in our case is the Allegany River.

In order to clean out the corners of our grit chamber and to hold sewage solids in suspension air jets have been arranged to agitate the grit in these areas.

There is an excellent paper on this type of air lift adaptation in Sewage Tanks Journal, Volume V, No. 3, pages 509-522, by H. Blunk, Engineer, The Emscher Genossenschaft, Essen, Germany, titled "A Contribution to the Design of Grit Chambers," translated by G. P. Edwards of New York.



Details of the Olean Pneumatic Grit Washer and Ejector

CATHODIC PROTECTION IN MECHANICAL SEWAGE FILTERS

By ALBERT B. KOZMA
Superintendent
Joint Meeting Sewage Treatment Plant
Rutherford, N. J.

MECHANICALLY cleaned sand filters for treating sewage became quite popular during the last decade due to their ability to produce uniform, "polished," effluent. While they temporarily fell into disrepute due to operating difficulties they are bound to stage a comeback if the causes of these troubles can be eliminated.

Much has been written on sewage sand filters by Zack in the *Sewage Works Journal* and a series of up-to-date articles was published by Streander in *Water Works and Sewerage.*[2]

These filters first followed the pattern of the old, backwash type water filters both in this country and abroad. The first modern type filter, the magnetite filter, was installed at Dearborn, Mich., in 1932. Many similar installations followed. The first silica sand filter with a hydraulic type of automatic washer was built by the Underpinning and Foundation Co., Inc., at South River, N. J., in 1937.

Both these modern filters have several features in common: a comparatively thin layer of sand (2 in. to 6 in. deep) is supported by copper or bronze screens which rest on steel gratings. A mechanical cleaner travels over the sand bed at certain intervals when the hydraulic head through the filter exceeds a certain limit. Some units are combined with circular settling tanks, located on their peripheries, others are self-contained, annular shaped or rectangular.

W. G. Laughlin of New York, inventor of the first magnetite filter, was the first to realize the disadvantage of using copper and steel submerged in sewage and developed the "Simplex" filter where the sand support consists of broken stone and underdrains. The International Filter Co. recently announced a new filter providing hard rubber screens and steel gratings for supporting the sand, the purpose of this combination being to eliminate galvanic corrosion. The manufacturers of the magnetite filters have been experimenting with wooden instead of steel gratings.

Investigation by the A.S.C.E.

The Second Progress Report of the Sanitary Engineering Division on Sewerage and Sewage Treatment published in the April 1944 issue of the *Proceedings, American Society of Civil Engineers,* pages 483 and 484,[3] says the following about magnetite filters:

"Effluent filters of crushed magnetite, arranged for cleaning by means of solenoids, have been abandoned at Denver, after six years of effort, to remodel the apparatus. Because of mechanical difficulties, uninterrupted operation could not be secured for even 30 days. The principal troubles were difficulty in insulating the solenoid windings so that the underwater service could be maintained, difficulty in maintaining a filter bed of uniform thickness, CORROSION OF FILTER SCREEN AND ITS SUPPORTS, and a loss of filter material. During the six years the actual efficiency of the filters could not be determined because of short periods of operation. The power usage was excessive. The removal of solids was relatively expensive.

"At Cleveland, in the Southerly Plant, Ellms also reports a high cost of operation and upkeep, WITH DIFFICULTIES SIMILAR TO THOSE AT DENVER, except for the insulation of solenoid windings. Little benefit was indicated in filtering the trickling filter effluent.

"At Minneapolis-St. Paul, the effluent filters were in service for only a few days each year from July 6, 1938 (for example, 39 days in 1942). The erosion and displacement of the magnetite sand on the beds proved a major difficulty. THE STEEL GRATINGS SUPPORTING THE SAND CORRODED AS AT DENVER."

The remarks pertaining to corrosion (stated in capitals by the author for emphasis) are equally applicable to silica sand filters.

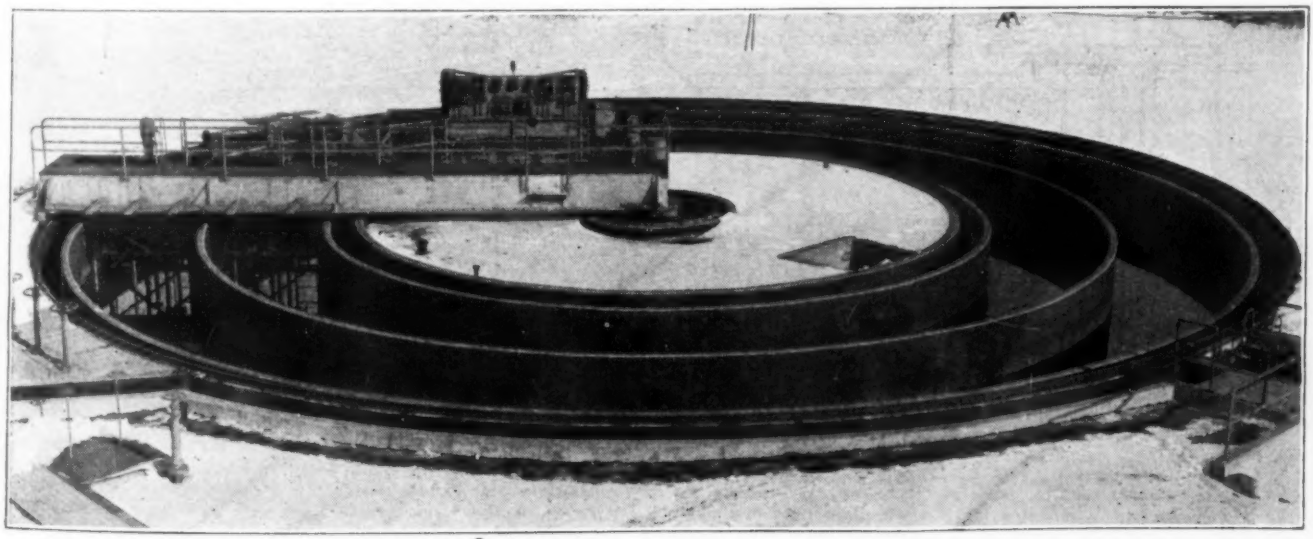
The Installation at Rutherford, N. J.

The Underpinning and Foundation Co., Inc., installed a silica sand filter at Rutherford, N. J., in 1940. The filter has two annular or circumferential shaped beds arranged concentrically, with a total effective area of 2780 sq. ft. and it is rated at one and one-half gallons per sq. ft. per min. for a peak flow of 6 million gallons per day rate. The actual flow to date has not exceeded 2.4 mgd. and either one of the two filter beds will handle the normal flow rates. This arrangement provides for a standby in case either one of the units has to be taken out of operation. The filter is preceded by chemical and biological treatments, the latter provided by four standard trickling filters and two secondary settling tanks, the settling tanks being designed for two hours' detention.

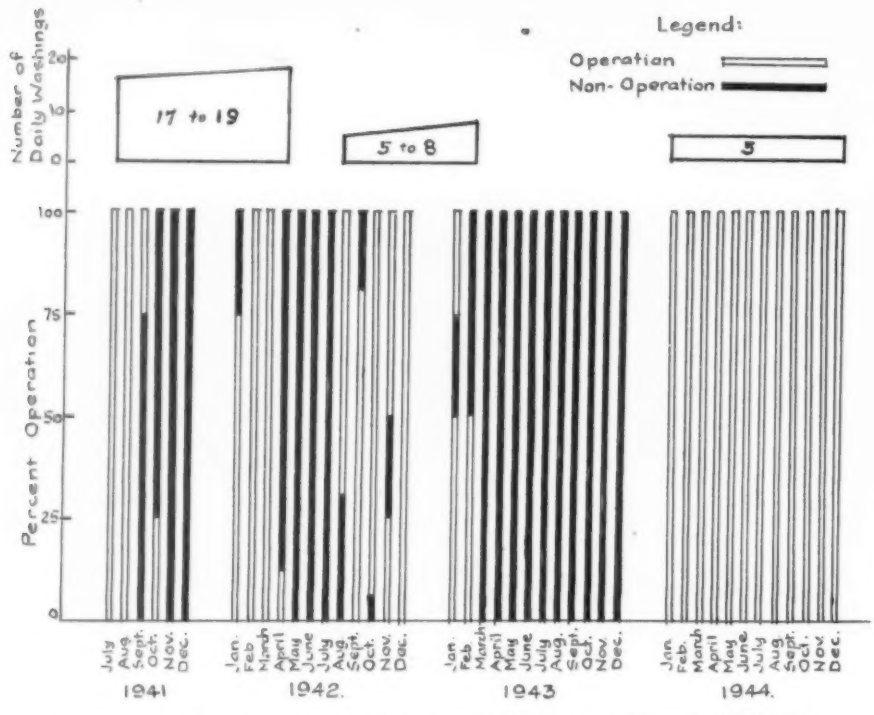
Operation started on July 1, 1941, and continued that month and through August, with an average of 17 normal mechanical cleanings of the sand beds per day. In September the equipment had to be shut down for three weeks for manual cleaning of the screens, and again for three weeks in October. In November and December the filter was not operated due to mechanical difficulties. Operation was resumed in January 1942, and only one week was lost to permit manual cleaning during this month. From February 1 we were able to operate continuously until April 4, the number of daily normal washes ranging between 18 and 19.

Summarizing the above period of operations from July 1, 1941, to April 4, 1942, the filter was running only 52 per cent of the total time. Following this period the equipment had to be shut down, all the sand removed, the copper screens and steel gratings taken out and trucked to the contractor's shop and cleaned with a power operated rotary steel brush. The gratings were left unpainted.

Operations were resumed on August 9, 1942, and continued until September 26, when the filter was bypassed for one week to permit manual cleaning. It was operated again between October 3 and November 7, November 14 and January 16, 1943, Jan-



The Effluent Filter of Rutherford, N. J.—Capacity 4 MGD.
(Consists of Two Annular Mechanically Washed Sand Beds, the Underdrainage System of Which Is Now Cathodically Protected.)



Operating and Non-operating Periods of Sand Filter and Record of Washing Frequency

(Cathodic protection was placed in operation Jan. 1, 1944. The filter has remained in continuous operation since and washings have been reduced to five daily—a record which speaks for itself.)

uary 23 and February 13 respectively, when it had to be shut down for the rest of 1943 to avoid repeated manual cleanings necessary to keep it in operation. During this whole period, from August 9, 1942 to February 13, 1943 the filter was operated 75 per cent of the total time and the daily normal washings averaged 5 to 8.

This time we decided to use chemicals for cleaning the copper screens and steel gratings. After removing them from the filter bed we bathed them in hydrochloric acid diluted with water in 1:2 proportion, using aniline oil as inhibitor, to clean off rust and scales. This was followed by a zinc sulphate rinse and clean water bath for neutralization. All the steel gratings were painted with various types of tar and asphalt base paints with the exception of three sections which were left unpainted to serve as control sections for test purposes.

In addition to painting, cathodic protection was provided and operation resumed on January 1, 1944. Since then operation has been uninterrupted and the daily normal washings have been reduced to five.

Theory of Corrosion and Cathodic Protection

Before installing cathodic protection the principal cause of our operating troubles was corrosion of the steel gratings, the product of the corrosion depositing and plugging the slots in the copper screens.

Galvanic corrosion is a well known phenomenon which occurs when two different metals are submerged in an electrolyte to form an electrochemical couple. In our case the copper screens and steel gratings are the two dissimilar metals, and these with the sewage as an electrolyte form a galvanic cell or battery. An electric current is generated between the two metals, this current transporting metallic and other ions from the steel and sewage to the copper screens. This, in our case, resulted in a hard, impervious deposit on the screens made up of ferrous and ferric carbonates and oxides and served to quite thoroughly seal up the minute openings in the copper screens. The formation of such a deposit results from the alkaline conditions surrounding the cathode in such a cell—in this instance the copper screens.

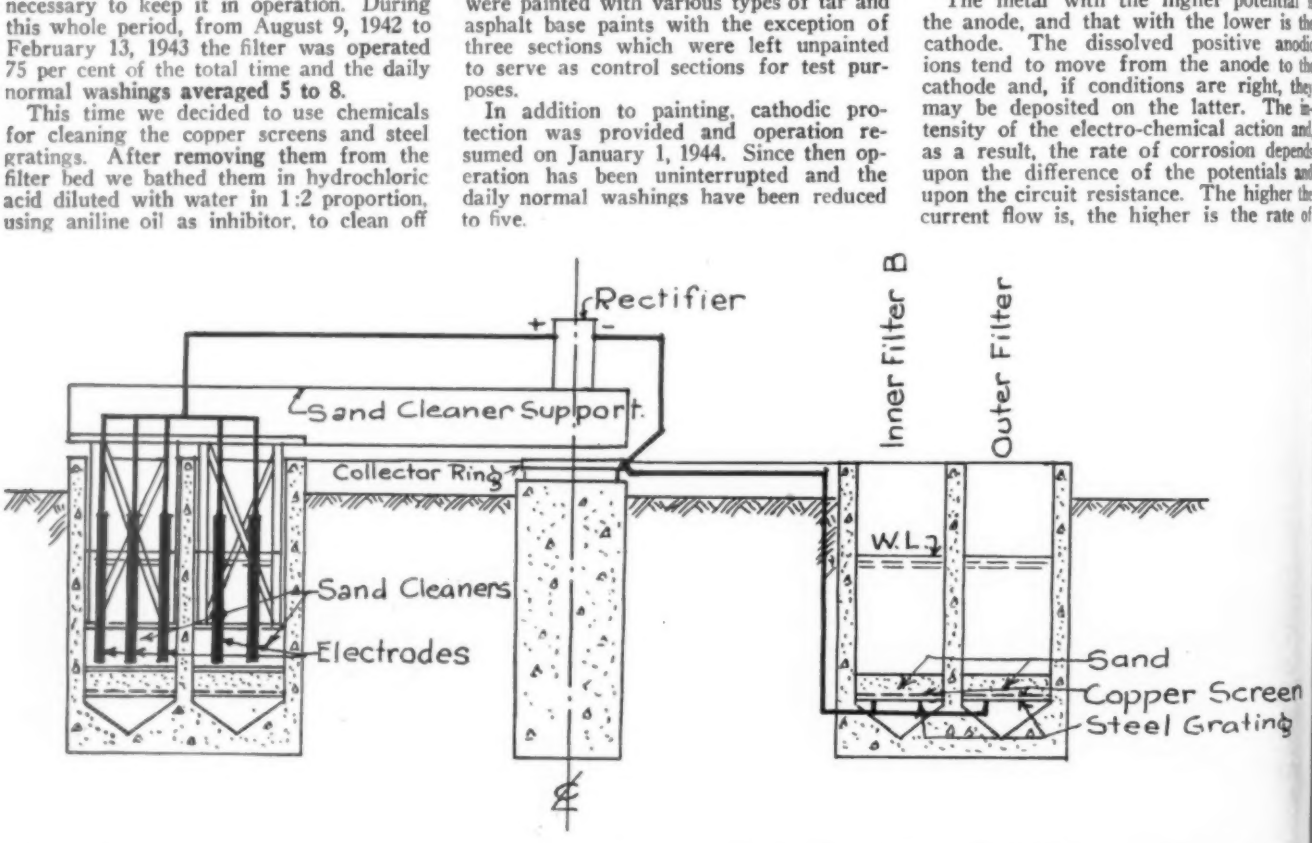
In general it will depend upon the relative position of the two metals in the electrochemical series, shown in the following table, as to which metal will pass into solution.

Electrochemical Series

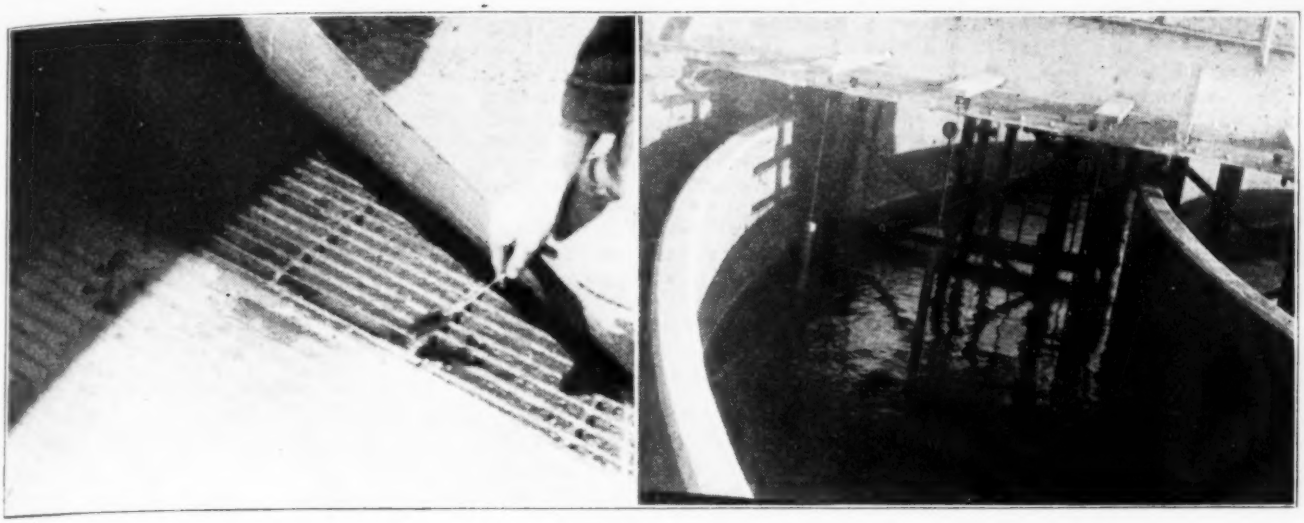
Metal	Potential Volts
Calcium	+2.70
Aluminum	+1.28
Zinc	+0.76
Iron	+0.43
Lead	+0.12
Tin	+0.01
Hydrogen	0.00
Copper	—0.34
Gold	—1.30

Note—This tabulation is only a partial list.

The metal with the higher potential is the anode, and that with the lower is the cathode. The dissolved positive anodic ions tend to move from the anode to the cathode and, if conditions are right, they may be deposited on the latter. The intensity of the electro-chemical action and, as a result, the rate of corrosion depends upon the difference of the potentials and upon the circuit resistance. The higher the current flow is, the higher is the rate of



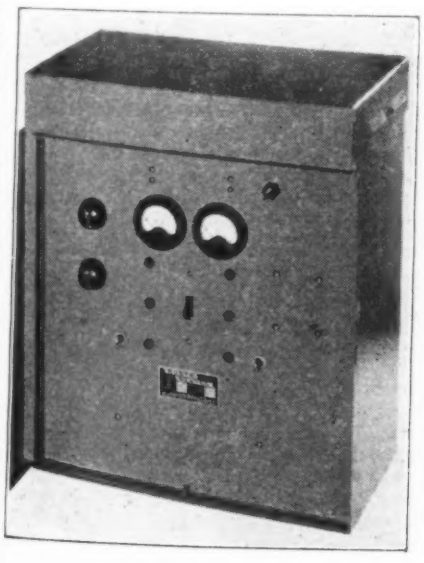
Note connection to rectifier from the steel support gratings for the copper-screen, on which rests the downflow sand bed. The five partially submerged graphite electrodes suspended from the sand cleansing unit travel around the filter with the revolving carriage, whose operation is intermittent and manually controlled. Since current for cathodic protection has been insignificant in amount the process is left on continuously. However when the cleaning mechanism is converted to automatic intermittent operation, some current saving may be realized by arranging automatic cutout of the rectifier when the cleaning mechanism is standing idle.



Left—Screen and Grating Inspection. Right—Bed Cleansing Carriage Showing Suspended Arches
(Note absence to choking deposits, but a thin protective deposition of ferric hydroxide principally and no copper. Beneath this coating the metal was clean and bright.)

corrosion. It is always the anode in a galvanic cell that is corroded.

On the other hand, if the negative or cathodic metal in such a galvanic cell (the copper screen in our case) can be neutralized by some artificial means, corrosion of the anodic metal will cease. The direct cause of the corrosion of the anodic (steel) grating is the current flowing from the grating to the copper screen, this current flow being due, as explained, to the difference in the potential of the two metals. This current flow can be neutralized or stopped by installing electric conductors (electrodes) in the form of rods in the sewage and **imposing upon them** a direct current from an outside source of such voltage and amperage that there will be flow of current from the installed conductors (anodes) to the steel grating. This stops the flow of current from steel to copper, and when done, the steel is no longer anodic but cathodic, therefore no longer suffers loss of metal or corrosion. In brief, the naturally anodic metal has artificially been made cathodic, and in the process it gains protection from further corrosion; hence the term "cathodic protection."



The Selenium Rectifier
(Rated at 8 amps. and 24 volts)

The new installed electrodes are now the anodes in our large galvanic cell and, if of such composition that metal is lost as the imposed current flows from them to the steel gratings and copper screens, these electrodes are called "sacrificial" anodes. Iron, stainless steel and to some extent graphite are of such nature. Platinum which is also used differs from the others in that it does not deteriorate and is permanent.

Cathodic Protection Equipment

In the search for some means of making the filter operation practical the author investigated the possibility of using cathodic protection. Arrangements were made with a company engaged in supplying the equipment for steel water tanks to make the installation.

The equipment consists of a selenium rectifier unit, rated at 8 amperes, 24 volts. Five graphite electrodes, 2½ in. in diameter, submerged three feet in sewage are installed in front of the cleaners (see illustrations), three in the outer and two in the inner bed so as to revolve with the cleaner. The negative side of the rectifier is connected to the copper screens and steel gratings and the positive side to the electrodes. Approximately 3.9 amperes of current is furnished at 12 volts to protect the screens and gratings for 2,800 sq. ft. of nominal filter area.

In the installation and use of this cathodic protection equipment special precautions had to be taken to get results. For instance, if anodic spots had appeared on the screens and gratings. due to improper bonding of the several sections of the screens, corrosion might have been accelerated instead of arrested. Adjusting the current for proper density was also found very essential.

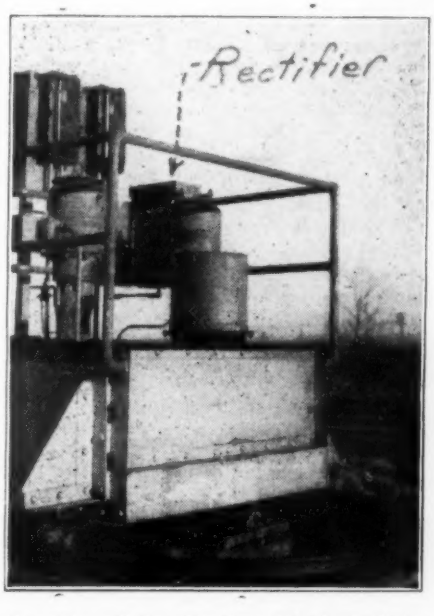
Results of Cathodic Protection

In observing the effect of cathodic protection the change in the appearance of the gratings was the most significant. The first observations were made four months after commencing operations and a ¼-in. thick, soft, brownish deposit was noted on the unpainted steel gratings. Chemical analysis indicated the absence of carbonates and the presence of iron and manganese hydrates. Copper was entirely absent. The quantity of iron present as Fe. was 52 per cent. The loss on ignition amounted to 20 per cent.

The deposit was soft, easy to wipe off, leaving a thin, black layer near the metal. This layer could be readily brushed off leaving the bright steel surface. Similar conditions were found also on practically all the painted gratings except that they were more irregular depending upon variations in the protective thickness of the paint. The painting apparently provided no effective protection and failed practically 100 per cent in a year. The copper screens were found tarnished but clean, the slots open, with occasional sand grains mechanically wedged in the openings.

The deposit contained much iron which was not a corrosion by-product but a protective precipitate caused by hydrolysis, induced by the current and the natural increase in pH at the surface of the cathodic steel. The presence of the iron in the deposit is readily accounted for by its use as a coagulent in the sewage ahead of the filter.

Before the cathodic protection equipment was installed a gradual increase in the hydraulic head took place through the filter after a few weeks of operation, due to the increasing plugging up of the copper screen openings. Following this installation, how-



Location of the Weather Proof Rectifier

ever, this head remained within a constant range, variation only taking place before and after washings.

The observations were repeated every four months during 1944 and showed substantially the same conditions, indicating that the soft layer forming on the steel gratings sloughs off after it reaches a certain thickness.

Operating Costs

Our records show that without cathodic protection the screens and gratings had to be removed and cleaned at least every 12 months. In between times other methods of hand cleanings had to be resorted to, resulting in a low percentage of operation. The first complete removal and cleaning in 1942 was done by the contractor; no cost figures are available. The second cleaning in 1943 including painting required $1,000 worth of materials and $600 of labor.

Since cathodic protection was installed over a year ago the filter has been operating without any decrease in efficiency. The electric current, based on a rate of 1.8c, per KWH, cost 4c per day or about $15 per year. The electrodes have lasted a year so far and when it will be necessary to renew them the cost will not exceed $30.

Conclusion

Since installing the cathodic protection equipment we have been operating our mechanically cleaned sand filter for over a year without any interruptions save some minor ones for mechanical repairs, and have lost practically no filtering time. We have made periodical observations during this time on the screens and gratings and noted the performance of the filter.

Based on these observations we can draw the following conclusions:

(a) Cathodic protection prevents corrosion of the copper screens and steel gratings.

(b) Prevents the clogging of the copper screens.

(c) Due to (a) and (b) the equipment can be continuously operated.

(d) Cathodic protection obviates the necessity of costly hand cleanings; consequently it helps to reduce maintenance costs.

We feel that our mechanically cleaned sand filters, after having been equipped with cathodic protection equipment, have fulfilled the original purpose of their installation, namely the production of a uniform, "polished" effluent in an efficient and economical manner. The exorbitant expenses and inconveniences caused by the frequent interruptions in operation have been eliminated.

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(4) G. W. Gleason.
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"DRY CLEANING" AIR DIFFUSER PLATES

By A. M. RAWN

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Editorial Associate, WATER & SEWAGE WORKS

EVERY once in a while someone does something that makes one stop and wonder why it has never been done before. Or, if ever done, why he has not heard of it.

Maybe you have been in Southern California when, due to "unusual weather conditions" the winter temperature drops below freezing and the citrus growers start the orchard smudge-pots to warm up the whole outdoors and keep the crops from freezing. If you have, you may recollect that upon such occasions the air in the orchard area is so filled with thick, oily smoke that one cannot see a hundred feet. This winter has been such a one and for a number of days early this month (January) millions of gallons of oil have been burned in the smudge-pots.

Now this may not seem to have anything to do with sewage disposal, but strange enough it does have.

The city of Ontario lies right in the heart of the citrus grove area and, in consequence, was encompassed in a dense smoke fog for some time. During this period the operator of the Ontario activated sludge plant noticed that the pressure on the air lines was steadily increasing at the blowers. Attributing it to the oily carbon in the air, as most likely responsible for the clogging of the diffuser plates, he made every effort to cleanse the air by straining it through several thicknesses of cloth over the air inlet to the blowers. The cloths were changed frequently but to no avail. And, pressures at the blower mounted from 5 to 7½ pounds over night.

Obviously the diffuser plates, which had operated for more than a year with no building up of pressure, had to be cleaned. The finely divided carbon and oil in the smoke had doubtless spread quite uniformly through the plate pores. The orthodox manner of cleaning would have been to remove the plates and clean them up with a solvent and, if not successful, burn out the volatile materials, possibly. The city engineer had other ideas, however, and instead of bringing the plates to the solvent the solvent was taken to the plates. A scheme for injecting the solvent into the air stream from the blowers was put into operation.

What was actually done was to slowly pump "Aviation" grade of gasoline into the airline and beyond the blower. Two gallons of gasoline was fed into the pipe slowly during a 24-hour period. It did the job all right, because during this period pressures dropped back to normal and the trouble was completely cured. So far, there has been no injurious effect upon the quality of the plant effluent or the behavior of the sludge.

This struck the writer as being a most unique method of overcoming a serious difficulty. Mr. Austin Burt, Ontario's city engineer was "the brains" behind this "solvent-solved situation"; and H. M. Ely, as chief operator of the plant, was "the brawn."

In his latest advice to the writer the "inventor" of diffuser dry cleaning states: "We have had to apply our gasoline remedy to the diffuser plates *seven* different times during the more than two weeks of smudge conditions. Each time the pressure was brought back to normal, and thus far we have been unable to detect any serious consequences in the operation of the plant. Altogether, we used seven and one-half gallons of aviation gasoline at the total cost of only $1.16 and feel pretty good at saving the trouble and cost of emptying the tanks, removing and cleaning the plates."

SLUDGE DIGESTION TEMPERATURE CONTROL WITH LIVE STEAM

By A. M. RAWN*

Chief Engineer and General Manager, County Sanitation Districts of Los Angeles County, Los Angeles, Calif.

THE accelerated rate of sewage sludge digestion at temperatures ranging from 85 to 95 degrees Fahrenheit necessitates the application of external heat to the digesting sludge mass. Currently, in most plants the heat is applied by circulating water of a given temperature through metal coils appropriately located on the interior walls of digestion tanks, or suspended in the sludge itself. The water may be jacket water from gas engines or constantly recirculated water heated in boilers of required capacity. Circulation is usually accomplished by pumping.

If fuel is at a premium, as, for instance, if power is generated from sludge gas at the treatment works and the entire gas supply is conserved for power generation, circulation of the gas engine jacket water presents definite advantages, and the difficulties attendant upon circulation of hot water through coils in the sludge mass is entirely warranted; but if there is a moderate excess of fuel which cannot otherwise be utilized in the operation of the plant or its features, it appears that there is another and better way of adjusting sludge temperatures.

Disadvantages of Coil Heating

Some of the disadvantages attendant upon heating sludge with circulating hot water in coils are:

1. Cost of the coils.
2. Cost of the pumping circulating water.
3. Removal of scale from exterior of coils as well as at times the interior.
4. Inflexibility of the operation, that is, the inability to heat sludge at any place but in tanks built and equipped specifically for that purpose, or to compensate for the difference between winter and summer sludge temperatures.
5. The periodic dosing of cold sludge into warm sludge mass.
6. Galvanic corrosion causing coil hangers to fail, allowing the coils to sag and leak or drop down.

Beginning in 1930 and up until last March, practice at the Joint Dispoal Plant of the Los Angeles County Sanitation Districts has been to heat digesting sludge by circulating hot water through cast iron pipe coils attached to the walls of the multi-stage sludge digestion tanks. While the process has been successful, it has exhibited all of the shortcomings hereinbefore noted but No. 6, which has occurred elsewhere. The most annoying deficiency has been the incrustation on (and within) the pipe coils, necessitating progressively higher water temperatures with correspondingly accelerated incrustations, ad infinitum, and the inability to maintain proper temperatures in the digesting mass throughout the year because of wide temperature range in the raw sludge from winter to summer.

Use of Live Steam for Direct Heating

Three or four years ago experiments were commenced at the plant looking toward the possible use of live steam for sludge heating. The experiments were moderate in scale and were aimed principally at ascertaining whether or not live steam would, through partial sterilization of the input of crude and seeding sludge, retard digestion. The information gained from this work was so conclusive as to the advantages of the method that a decision was made to use live steam in sludge heating when it became necessary to expand the sludge digestion facilities at the plant.

Construction of a third battery of multi-stage sludge digestion tanks was commenced as a WPA project in the summer of 1940, but with difficulties attendant upon the current crisis in national affairs and the present emergency, the battery was not completed and placed into operation until March, 1942. By the time the tanks were completed, the remaining sludge digestion features at the plant had reached saturation and every spare tank in the area of any description was filled with digesting sludge. Unfortunately, however, only the two 1930 batteries could be heated, consequently sludge digestion in the remainder of the unused tanks and basins in and about the plant area was greatly retarded because of lack of temperature control.

With the advent of March the situation was acute, but by that time the new battery of sludge digestion tanks was completed, including the 70 hp. boiler installation (see picture) designed to utilize sludge gas for fuel and to provide steam for heating sludge at the suction pumps of the two raw sludge concentrating wells.

The picture changed immediately. Sludge in the temporary tanks, in which the temperatures approximated 70 degrees, was recirculated through the crude sludge concentration tanks along with raw solids and raised to a temperature of 90 to 95 degrees at the transfer pump suction, then returned to the tanks, or transferred to other digesting units. The newly completed battery was filled with sludge and seed which had been raised to a temperature of 90 degrees F. and which maintained temperatures of 85 to 90 degrees without further heating until digested. A large partially digested sludge mass in the holding pit was warmed and construction immediately commenced upon covering certain unused sedimentation tanks in the plant with temporary gas tight covers of timber and roofing construction. These fixed covers converted these tanks into useful digestion units—a feature which could not have been accomplished otherwise without great cost for heating coils. One trio of these tanks, illustrated here, has been completed and is functioning with complete success.

The Districts' Joint Disposal Plant was originally constructed as an activated sludge sewage treatment works and functioned in that capacity from 1928 to 1938. Upon completion of the ocean outfall, the activated sludge features were removed from the plant and it was converted into a primary sedimentation works with separate sludge digestion. Looking to the day of an ocean outfall, the former aeration tanks (twenty-two in number) had been designed primarily for use as plain subsidence tanks, and eight of them were immediately equipped with sludge removal mechanisms. The fourteen remaining tanks will be equipped in a similar manner as increased flows at the works require their use, but in the meantime they are idle and it is a trio of these tanks—each 12½x12½ feet in section and 175 feet in length—which have been converted into sludge digestion units. Three more sets of tanks will be similarly equipped this summer.

Plant Practice

Present practice at the plant is to transfer raw sludge from eight sedimentation basins to two sludge concentration tanks. Sedimentation basins are 12½x12½ feet in section and 175 feet long. Sludge concentration tanks are of like cross section but are 50 feet in length and lie side by side, their long axes parallel. Each concentration tank is equipped to drain to a small

70-HP Boiler Used to Supply Steam for Direct Heating of Mixed Sludge Input to Coil-less Digesters—Formerly Sedimentation Tanks

*Editorial Associate, Water Works and Sewerage.

bottom hopper from which the sludge transfer pump suction draws. As the concentration tanks are being filled with raw sludge, 20 per cent by volume of digested sludge is returned thereto for "seed." When the tanks have been filled with the mixture, the entire mass is transferred to the designated sludge digestion tank, and as the transfer pump starts, live steam is ejected into the tank hopper from which sludge is drawn.

Advantages of the System

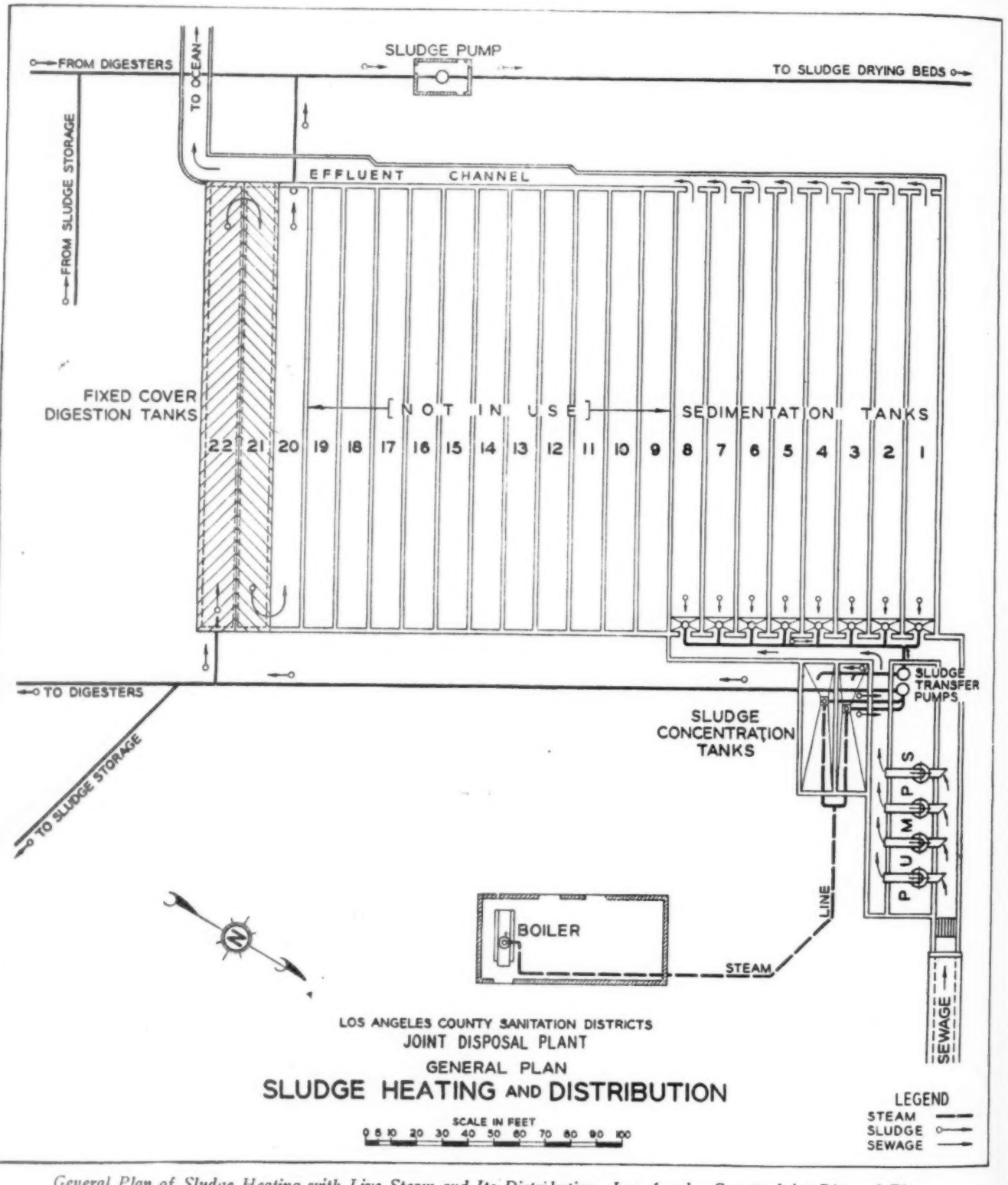
The system has many advantages:

1. It is entirely flexible, permitting the control of sludge temperature in any receptacle which will hold sludge, whether it be an earthen pit, a lined retention chamber—covered or uncovered—an unused tank or basin, or a regulation sludge digestion unit.

2. The adjustment of sludge temperature is not at all dependent upon the temperature of the incoming sludge. The adjustment is made by either regulating the flow of steam at the pump suction or the speed of the transfer pump.

3. It eliminates entirely the use of heating coils with all of their attendant difficulties.

4. It permits a 10 degree F. rise in temperature in more than 100 gallons of wet sludge, with but one gallon of water applied as steam, thus less than 1 per cent is added to the sludge mass as water.



General Plan of Sludge Heating with Live Steam and Its Distribution—Los Angeles County Joint Disposal Plant.

5. It admits of dosing warmed sludge into the warm sludge mass whereby the temperature of the digesting sludge is not disturbed or changed during the process of dosing.

6. The heating and transfer of sludge from the concentration tanks to the digestion tanks—or whatever structures in the area are being used for that purpose at the time, is accomplished in about four hours daily. The total amount of raw sludge transferred to digestion every day approximates 175,000 gallons, to which is added 45,000 gallons of seed before the sludge is warmed up. Said sludge usually drawn from the multi-stage digestion tanks—but occasionally from tthe sludge concentration pit—and the mixing of raw and seed sludges prior to transfer to a digestion chamber, results in a lessened disturbance of seed to raw sludge ratio in any of the tanks in which the mass is discharged.

The foregoing are about the main advantages of this new adventure. It has the disadvantage of using more water than the water circulation system, and it likewise does not take advantage of heat transferred to the jacket water of sludge gas engines, although even this may eventually be possible when the new "Vapor-Phase" cooling system is perfected, wherein the circulating water is constantly maintained above the boiling point and live steam given off as the pressure is released in recirculation.

Question of Odors

Lest there be some misgivings about odors emanating from raw sludge heated to temperatures of from 85 to 95 degrees F., it is worthy of note that the contents of the sludge concentration tanks have been raised to a temperature of 130 degrees F. without any noticeable or distinguishable change in the odor of the contents, and since there has been some question regarding vapor-lock in a sludge pump when live steam is injected into the suction line within 20 feet or so of the pump itself, it may be stated that the experience at the District's disposal plant indicates that the sludge pumps operate as smoothly with the steam injected into the suction as without.

The steam boiler at the Sanitation District's disposal plant is operated at a pressure of 30 pounds per square inch. The only advantage in this over a much lower pressure is that the steam feed water pump will not operate at less tthan 30 pounds; otherwise the pressure would be maintained at below 15 pounds. Because of the latent heat factor in live steam, the gallons of sludge which may be heated by one gallon of water converted to steam at zero pressure is almost equal to the amount which may be converted at 125 pounds per square inch, the difference being in the ratio of approximately 110 to 114. This approximate computation is based upon the use of saturated steam and an assumed heat capacity of sludge of 1 B.t.u. per pound per degree Fahrenheit.

Use of Non-Critical Materials and Simplicity a Feature

The process is so easily installed, so cheaply operated, and so extremely flexible, and has proven so successful in operation at the plant described, that the information is passed on for the benefit of those who may encounter some of the difficulties herein enumerated with the present system of heat transmission. It also is detailed here to some extent to indicate that in this paricular time of shortage of materials and restrictions upon the use of available materials by WPB and other Federal agencies, existing tanks or basins in or about the plant not otherwise in use may be covered with inexpensive tops of some sort comprised of materials which are not deemed critical at this time, and converted directly into controlled sludge digestion tanks for use during the emergency. The potentialities of the system become apparent when one visualizes its complete flexibility. The fact that it has no deleterious effect upon sludge digestion is a strong argument in its favor.

CLEANING ENCRUSTED PIPE LINES AND VACUUM FILTERS WITH INHIBITED MURIATIC ACID

By K. L. MICK
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CONSIDERABLE muriatic or hydrochloric acid has been used in our plant for removing carbonate scale from pipe lines, filter cloths and vacuum filter parts. To minimize the acid attack on metal parts of the equipment and on pipe lines, it was deemed advisable to use an inhibitor with the acid. Certain protein materials such as bran, or organic amino compounds such as aniline oil (aminobenzene, $C_6H_5NH_2$) are capable of retarding the action of strong acids on metals by preventing or slowing down the evolution of hydrogen at the metal surface in the reaction—

$$Fe + 2HCl = FeCl_2 + H_2\uparrow \text{ (gas)}$$

They are called inhibitors and are believed to function by raising the hydrogen overvoltage on the metal, i.e., they raise the potential required to force off the protective blanket of hydrogen as gas bubbles. Unless sufficient potential is available, the hydrogen will tend to accumulate on the metal surface and the reaction written above will slow down or stop, thus protecting the metal from further action of the acid. However, the corrosion inhibitor will not affect the action of acid on the carbonate scale which it is desired to remove, the reaction being—

$$CaCO_3 + 2HCl = CaCl_2 + Co_2\uparrow + H_2O$$

Twin-Cities Plant Practice

The acid used at this plant is commercial 18° Bé. muriatic acid (28 per cent HCl), purchased in 125 pound carboys. Some laboratory tests were made to determine the proper proportion of aniline oil to acid. For these tests a number of 1x3 inch panels of 23 gauge mild steel were immersed in acid solutions of various strengths, 0.7 per cent HCl, 2 per cent, 5 per cent and 10 per cent. One of each of these acid solutions was left untreated with the aniline oil to serve as a control comparison, and aniline oil was then added in various dosages to each of the acid solutions. In evaluating the rates of acid corrosion of the steel, use was made of Speller's formula, which takes into account the loss in weight, the area exposed, and the time of exposure.

The results indicated that a 2 per cent aniline oil dosage (by a weight of pure HCl) could be used with the weaker acid solutions, up through 5 per cent HCl, while stronger acid solutions should have a 3 or 4 per cent aniline oil dosage for maximum protection of metal parts.

With a 0.7 per cent HCl solution (which is the initial strength obtained in our plant when one carboy of commercial muriatic acid is added to about 600 gallons of water in the filter pan), a 2 per cent aniline oil dosage will cut the corrosiveness of the acid by 44 per cent, according to the laboratory tests. A 2 per cent aniline oil dosage in a 5 per cent HCl solution cuts the rate of corrosion nearly 97 per cent, while in a 10 per cent HCl solution a 4 per cent aniline oil dosage was required to reduce the rate of corrosion by 69 per cent.

Added to a one-carboy acid bath for a filter, 300 ml. of aniline oil will reduce the corrosiveness of the acid about 44 per cent for the small cost of 25 cents. For protection of the screen and the thin nailheads in the wood splines, this added precaution would seem justified even though the rate of corrosion with an acid solution of this strength is apparently quite low.

The application of the acid bath is very simple. Sufficient water is run into the filter pan to just submerge a portion of the drum (about 600 gallons at this plant). The aniline oil treated carboy of acid is then syphoned into the water, with the filter drum and agitator in operation. After two or three hours the acid is usually pretty well spent (a titration test will tell) and the solution is then drained off and the filter washed with the water sprays. If the filter and cloth are badly scaled, more than one carboy of acid may be needed.

The filters at this plant are now given an acid bath after about 350 hours of cloth life, with the cloth and screen left in place. This treatment increases the economical life of the filter cloth to 500 or 600 hours and at the same time removes the scale from the screen and splines.

To clean the pipe lines of carbonate scale, the inhibited acid bath is recirculated through the lines. The scale is disintegrated and sloughs off.

[Ed. Note—It is quite evident that the use of inhibited acid applies in water purification plants as well as sewage plants—also for cleaning small pipe lines of iron scale.]

CORROSION OF SLUDGE DIGESTER PARTS

Corrected by Application of Cathodic Protection

By G. A. PARKES
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AFTER fourteen months of service it was a decided shock to find that the metal parts within the sludge digestion tanks of the Terminal Island Treatment Works of Los Angeles had suffered marked corrosion. Almost every metal part that had been in contact with sludge, scum or supernatent liquor had suffered attack. Pitting had penetrated to a depth of five-sixteenths of an inch in a few places, while in many places extensive areas showed corrosion varying from one thirty-second to one-eighth of an inch below the original surface.

Certain peculiarities were noticed. One side of a structural member might be severely corroded while the other side of the same member remained entirely untouched. The hot water coils of galvanized wrought iron were badly attacked in some places and in others the original galvanizing was intact. The hooks supporting the coils were likewise affected.

No one part of the tank was affected more than another and all metal parts in the tank were affected. It so happened that all these parts were of iron or steel and no brass, aluminum or other non-ferrous metals were present. Interestingly, the galvanized wrought iron pipe had been attacked as badly as the structural steel of the sludge stirring mechanism. The digester in question is a single stage, fixed cover, heated, concrete tank, 75 feet in diameter by 27 feet sidewall height.

The sewage treated at the Terminal Island plant averages about 3.0 million gallons daily and includes a considerable industrial load from two fish canneries. Solids and oil in the cannery waste caused a thick tenacious scum to form in the digester.

What the Inspection Revealed

To examine conditions, it was decided to shut the plant down and drain the digester and make a thorough inspection.

On entering the tank for inspection, while it was being drained, the writer felt several manhole steps bend under his feet. Later, it was found that these steps, originally ¾ inch in diameter, were eaten nearly through. On the other hand, it was of peculiar interest that some of the steps were as good as new.

The sludge was transferred to the clarifier and decantation tanks for storage. This saving of sludge proved to be a fortunate thing, for it not only provided a sufficiency of seed sludge when the digester was again placed in operation, but it also supplied the real clue which led to the final solution of the corrosion problem at Terminal Island.

As soon as the tank was clean, and safe to enter without wearing hose masks, the surprising conditions were discovered. Out of all the mass of facts observed and noted only two observations seemed to be favorable. There was no indication that the concrete of the tank itself was damaged, nor was there any evidence that the steel reinforcement embedded in the concrete had been attacked.

This last fact was a good deal of a puzzle, but at the same time it was a Godsend, for if the reinforcement had been corroded, the concrete would have been cracked beyond repair and the whole tank a total loss. The effects of the corrosion were so serious and had taken place in so short a time, that it was evident that unless the cause were discovered and eliminated, the entire mechanism and perhaps also the tank would soon be destroyed.

Causes Considered

Several theories were advanced as to the cause of the corrosion, none of which proved of any help in the solution of the problem. Inquiries at the time failed to reveal any similar conditions elsewhere, although some cases of corrosion in digesters have been reported more recently.

The sludge was not altogether normal, due to the presence of the fish waste already mentioned, although the pH had been consistently above 7.0. This fact seemed to eliminate the possibility of acid corrosion.

Later investigation showed that the sludge and scum were high in either sludge matter, probably high in sulphides and extremely high in chlorides. The latter, which was due to large quantities of sea water and brine used by the fish canneries, has sometimes amounted to 2,000 ppm. in the raw sewage entering the plant during the sardine packing season and for some unknown reason is concentrated to as high as 5,000 ppm. in the sludge in the digester. These figures vary widely, the average being less than one-half the above. These facts, particularly the chlorides, undoubtedly had a bearing on the case, but were not known at the time the corrosion was discovered.

In the meantime, while the theorizing was going on, reconstruction work was under way in the digester under the direction of the writer. The original scum breaker was removed and a short, stiff truss was installed with vertical angles which meshed with stationary combs bolted to the roof. Figures I and II show some stages of this work. The hooks, which supported the hot water coils, being no longer safe, a system of wooden racks of redwood lumber was devised by the writer. These racks were held together by birch dowels, as wood is known to be very resistant to digestion processes. Part of these wooden pipe racks can be seen in Figure II.

The Investigations

The suggestion was finally made that the corrosion was similar to that caused by galvanic action or by electrolysis, the last being usually caused by stray electric currents. As this theory seemed to be more reasonable than most of those advanced, investigations were undertaken to find the source of such currents. These studies were made while the repairs were going on.

Alternating current is used for lighting the plant and for power to operate the digester mechanism, but all previous research has shown that alternating current is rarely, if ever, a cause of electrolytic corrosion to any serious degree.

A well known expert on electrolysis inspected the plant and gave the opinion that the corrosion was caused by stray direct currents from street railway operation. It was found, however, that there are no electric railways on the island and that there is no direct current produced or used in any appreciable amount. Furthermore, the only possible path by which such current could enter the plant was by the city water main. The water service pipe was disconnected and it was found that a higher electrical potential existed in the plant system than in the water main, indicating that the source of current was *inside* the plant rather than outside of it. This proved an important discovery.

At this time, the services of Mr. Otto Wiemer, Electrical Engineer of the Department of Building & Safety, of the city of Los Angeles, were obtained, who, with the writer, made an extensive series of investigations as to the source of the electric current which was apparently being generated within the plant.

A complete description of all the investigations would be far too lengthy to be included in this article. Many experiments and unsuccessful attempts were made to correlate the electrical potentials which were found to exist between the different parts of the plant. Various types of grounds were used, chromium rods, copper sulphate sponges, and what not. But the chief difficulty was the inability, with these methods, to reproduce any observed reading on two successive days.

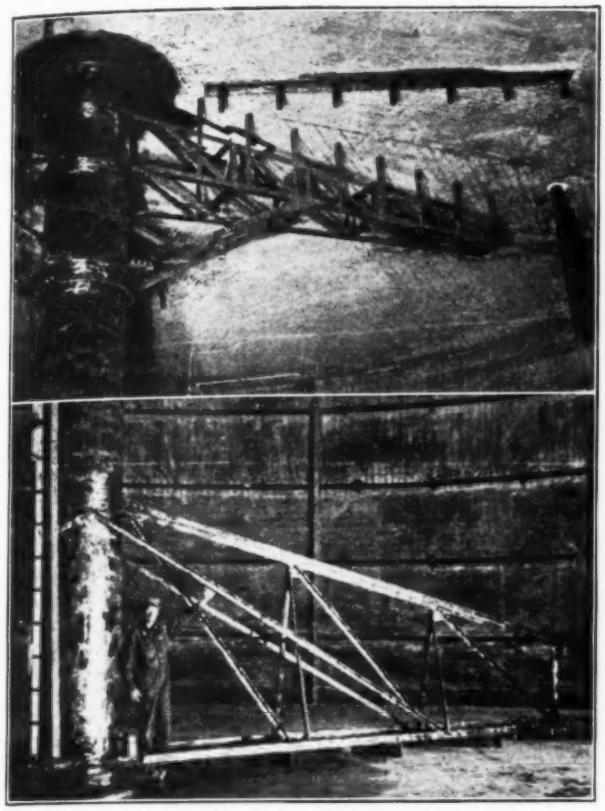
The "Bench-Mark" Method

Finally a method was decided upon, which for want of a better name was called the "bench-mark" method. This simply consisted of using one point (a conveniently situated water faucet), as a reference point and observing the potentials—i. e., voltages, of all other points in the plant, with reference to this one point. Several hundred readings were made and recorded showing values, positive or negative, with reference to our "bench-mark." It was found that these readings could nearly always be checked quite closely when the work was repeated on subsequent days.

The equipment used for this work consisted of a very sensitive voltammeter, known as a Rawson Junior "Multi-meter," with full scale readings in decade arrangements from as low as two millivolts to one thousand volts and from 0.1 milliampere to one ampere. Several hundred feet of No. 12 rubber-covered wire on a spool, and numerous clips and points for making connections, completed the outfit.

The Clarifier Proves a Giant Galvanic Cell

It has already been stated that during the reconstruction of the digester, the plant had been shut down and the contents of the



Figs. I and II—Digester Interior

Showing mechanism protected with Bitumastic coating, which reduces current requirement and enhances efficiency in Cathodic protection. (Above)—New scum-breaker, with stationary combs bolted to roof. (Below)—Sludge-sweep mechanism and heating coils on tank walls, both protected with "Bitumastic" enamel.

digester transferred to the clarifier and decantation tanks for storage.

It so happened that most of the first readings were made at scattered points throughout the plant and showed only small voltages above or below the "bench-mark." However, finally, a series of increasing potentials noted led to the clarifier, in which digested sludge was stored. Here a difference of four hundred millivolts (0.4 volts) was found between various parts of the clarifier piping and steel work and our "bench-mark." Similar but lower differences existed between parts of the decantation tanks (also filled with sludge) and the "bench-mark."

The investigation was continued and readings made of differences of potential between the "bench-mark" and several hundred points throughout the plant. These points included hot and cold water systems, sludge pipes, electrical conduits, exposed metal parts in tanks, reinforcing steel in various structures and even hand rails and the wire fence enclosing the plant property.

The readings varied over a wide range, positive or negative, to the "bench-mark." But, from a study of all the readings, it became evident that greatest differences of potential existed between the point of reference and those tanks in which the digesting sludge was stored.

Figure III—A table which appears later—reveals the method of keeping the notes.

The only possible inference which could be drawn from these observations was that in some manner, not entirely clear, the said tanks were acting as huge galvanic wet cells and were actually producing direct current. This current was leaking out through many inter-connected paths throughout the plant and was returning through other paths to complete the electrical circuit.

In applying this "wet battery" theory to the digester, which was still undergoing repairs, it was possible to conceive that the corrosion already described could ahve been caused in this way, provided the corroded parts were "anodic" (positive), and some other parts were "cathodic,"—i. e., negative. In galvanic action, current flow is always from the positive to the negative electrode.

It is well known that when two dissimilar metals are immersed in an electrolyte and connected externally, a current will flow from one electrode to the other and that one of the electrodes (the anode) will pass into ionic solution in the process. Such action is known as galvanic action. It is also well known that it is not necessary to have entirely dissimilar metals, such as copper and zinc, for such a condition to exist. Even electrodes of the same material, such as iron, which by reason of difference in area, or surface condition or partial protection, will behave in the same manner and one of the electrodes will be eaten away.

Laboratory and Model Studies

A number of tests made in the laboratory, using numerous samples of iron and steel, and sludge liquor for electrolyte, proved that electrolytic corrosion could take place. One test was made with two small grids of black iron bailing wire of exactly the same size and shape. One grid was used bare and the other was cast in a plaque of concrete, one inch thick. Both grids were immersed in sludge liquor and showed a definite flow of current when externally connected. Diagram No. 1 shows the well known principle of the galvanic cell and the close relation to our sludge cell, which behaved in a similar manner.

FIG. III—TYPICAL NOTES OF POTENTIAL DIFFERENCES USING THE "BENCH-MARK" METHOD

Location	Potential* Millivolts
6-in. C. I. pipe to east sludge beds	+ 21
2-in. W. I. pipe—sprinkler system	+ 3
Reinforcing steel—digester wall	+ 36
Wire fence—south property line	— 13
Telephone conduit—office	+ 18
Hand rail—pump house	+ 42
Discharge—high pressure wash pump	+150
4-in. C. I. suction—effluent wash at clarifier	+400**
Clarifier sludge outlet pipe	+385**
4-in. C. I. gas pipe at regulator pit	+ 32
Decanter tank—sample pipe	+108**
Decanter tank—float guide	+210**
Gas holder frame	+ 32
Digester—supernatant overflow pipe at ground line	+ 18
Reinforcing steel—venturi flume structure	+ 11

*Potential expressed in millivolts between the water-faucet "bench-mark" and the equipment listed, + meaning flow away from the unit listed.

**Digester sludge was stored in these tanks.

A model was then constructed to simulate, in principle, the construction of the digester. The model was made of concrete, sixteen inches in diameter and twelve inches high, with walls and bottom two inches thick. A cage of bailing wire was cast in the walls and bottom to represent the reinforcing steel, while a coil of wire supported inside the "pot" and in contact with the cage represented the hot water coils. The sludge stirring mechanism was represented by a grid of wire supported in the middle. Several wires were brought out for electrical connections and the "pot" was filled with sludge liquor.

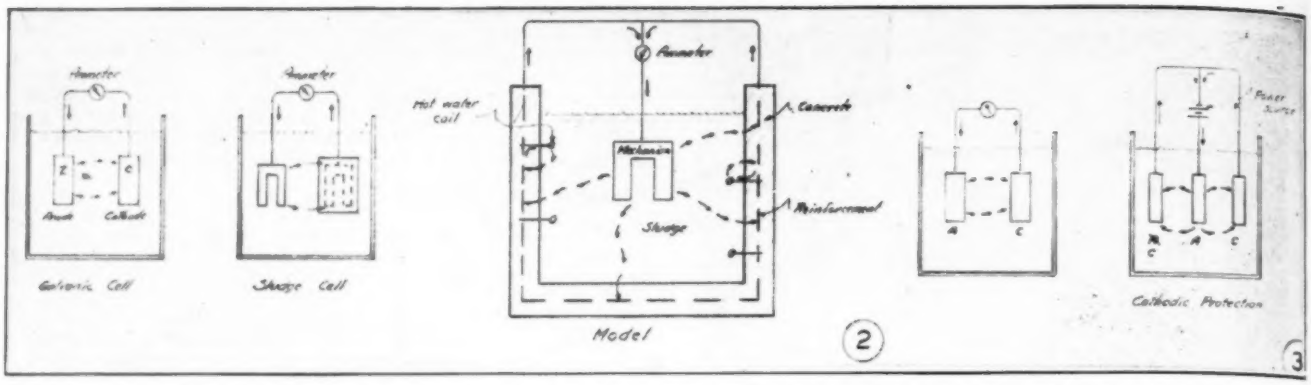
Diagram No. 2 shows the arrangement of "pot" model. The parts indicated as "reinforcement," "hot water coil" and "mechanism" were baling wire.

Readings made with the sensitive voltmeter showed that current flowed through the instrument from the wire cage which was encased in concrete to the grid which was suspended in the liquor. This proved that the "pot" was acting as a battery and that a self-generated current passed from the wire grid (anode) through the liquor electrolyte to the wire cage in concrete, which was the cathode. The current passed back through an external wire to the anode, thus completing the circuit. Current also probably flowed from the wire which represented the hot water coil to the wire cage, and back to the coil through the supporting wire, although this could not be proven.

However, after exposure for about three weeks, with the cage externally connected to the grid, a noticeable amount of corrosion was found to have occurred in wire representing the hot water coil, as well as in the grid representing the sludge and scum mechanism.

It was suggested that a possible source of electric current might be the maze of piping which connects the various parts of the plant. These pipes of various materials, are for the most part, buried in the damp, salty sand of the plant site and may at times be in brackish ground water.

This theory was based on the well known fact that pipes passing through varying types of soils are subject to electrolytic corrosion. In this case, the pipes buried in the ground would be cathodic while the other ends, being in contact with the sludge in the digester, would be anodic and, therefore, would be corroded. However, the experiments with the "pot" model, already mentioned, proved that current was produced when the model



Diagrams 1-2-3—*Revealing Similarity Between a Simple Galvanic Cell and That Produced With Electrodes in Sludge Liquor, as the Electrolyte*

(1) *Galvanic Cell and Sludge Cells.* (2) *Concrete Model of Sludge Digester Used in Study of Current Flow Resulting From Galvanic Action.* (3) *The Simple Galvanic Cell After the Introduction of a Sacrificial Anode Between the Two Electrodes and Reversal of Current Flow. Thereby, What Was Originally the Anode Becomes Another Cathode, Thus Producing So-called "Cathodic Protection" When the Imposed Current Reverses the Flow of Ions.*

was standing on a bench and *not* in contact with the ground—i. e., was in nowise grounded.

A test was made to simulate conditions to test the above theory. The "pot," partly buried in the sand, was connected to a quantity of junk iron buried nearby. This sand was well-soaked with ground water and conditions of current flow noted. It was found that a small current, probably not over 15 per cent of the total, was produced by the buried iron and the remainder (85 per cent or better) was produced inside the "pot." It was concluded that, due to the smaller relative area and to faulty electrical contact, the piping system of the plant would deliver but a negligible amount of current to the digester.

The Digester Studied

After a very careful consideration of all the foregoing evidence, it was concluded that the corrosion which had occurred in the digester had been caused by an electrolysis due to a self-generated or galvanic current within the digester itself.

Further investigation was made to find the cause of the "spotty" condition of the corrosion in the digester, particularly as to why some of the manhole steps and pipe hangers were severely attacked and some were not. It was found by passing a small electric current from a flashlight battery through the various parts, that the steps and hooks which were corroded were apparently in good contact with the reinforcing steel in the concrete walls of the tank, while those which were not corroded were in poor contact or not in contact at all. This poor contact would prevent the completion of an electrical circuit without which electrolytic (galvanic) corrosion could not occur.

It could only be assumed that the "spotty" conditions of structural steel members and some portions of the piping was caused by the fact that some of the original bituminous paint coating adhered to some areas and caused a concentration of current on the unprotected areas.

Considering the digester as a whole, the electrolytic conditions which could have caused the corrosion were now considered as being somewhat as follows:

The hot water pipes, being directly exposed to the sludge and therefore, by reason of their environment, dissimilar from the steel of the reinforcement, acted as anodes. Current flowed through the sludge electrolyte to the cathodic reinforcing steel embedded in the damp concrete and thence back to the pipes through the supporting hooks which were in contact with the steel. The pipes, being anodic, were eaten away. (By referring to Diagram No. 2 and imagining that the external lines leading to the ammeter represent the massive steel and concrete roof structure, the reader will have less difficulty in following the writer's explanation.)

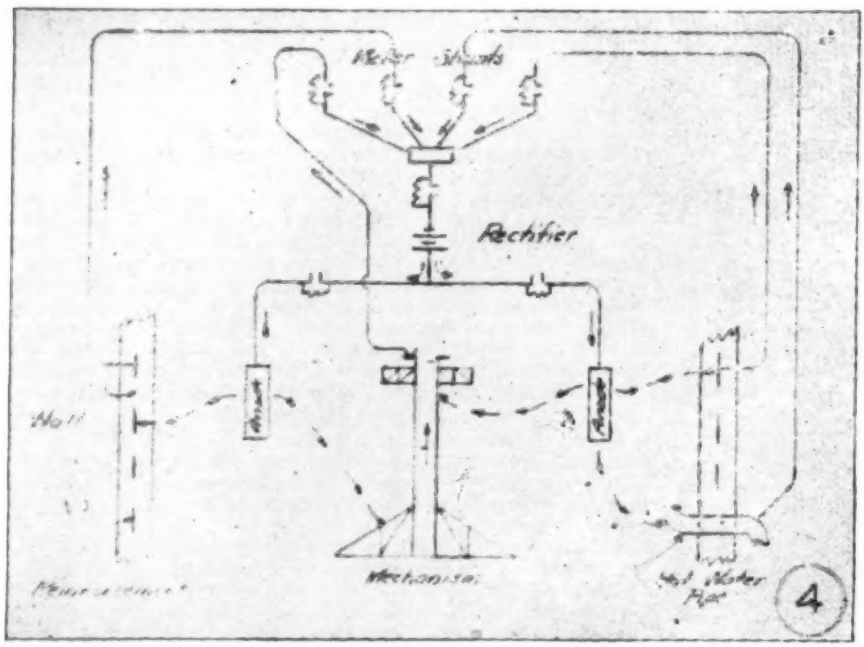


Diagram 4—*Cathodic Protection Diagram as Applied to Sludge Digesters Sketch Reveals Arrangement of Sacrificial Anodes and Reversed Current Flow Onto Metal Parts of Digester to Be Protected, and Its Return Through Metering Shunts. The Imposed Current Follows the Path of Least Resistance, Which Is to Exposed Metal Where Corrosion Is Most Active and Protection Most Needed.*

In the case of the sludge stirring mechanism, the structural steel members were also anodic and current passed through the sludge to the reinforcing steel. This steel, being in contact with the roof of the tank, itself of reinforced concrete with steel beams, passed the current to the rotating sludge mechanism through the driving machinery and thrust bearings, thus completing the circuit. Here again, the steel members of the stirring mechanism, being anodic, were corroded.

While the data obtained in the investigations did not definitely prove that the corrosion had been caused in the manner above stated, it seemed that all of the facts fitted the theory and that no other theory fitted all of the facts. It was therefore decided to proceed to devise protective measures on this basis.

Protective Measures Adopted

At first, an effort to insulate the various parts was considered. This would have been extremely difficult, if not impossible, and at best would have been unreliable, due to the many possible paths for the flow of current. It could not have been accomplished without extensive reconstruction of the tank.

Protective Coating

It was decided to sand blast all of the exposed metal in the tank and to cover the parts with a good bituminous coating. After sand blasting, the parts were given a prime coat of Wailes-Dove-Hermiston Corporation's "Bitumastic" solution, followed by two

coats of hot "Bitumastic" enamel, mopped on. This material produces a thick, rather rough and brittle coating but when properly applied gives good protection. (See Figures I and II.) A coating, however, on such surfaces, cannot be applied so as to give 100 per cent coverage and it was realized that additional protection by other means would be required. In fact it was quite likely that a 99.9 per cent covering would be worse than no covering at all. For if the cause of the corrosion was to continue unabated, all the attack would be concentrated on the uncovered areas. This would result in the prompt and complete failure of the unprotected parts.

Cathodic Protection Adopted

After considerable study and inquiry, it was decided to test the method of anti-galvanic action known as "cathodic protection" which has for some time been used to protect oil, gas and water pipe lines from external soil corrosion; and more recently applied to water towers and tanks for stopping internal corrosion.

This method of protection has as its basis the fact that if a metallic surface, which would otherwise be anodic and therefore subject to electrolytic corrosion, be made cathodic by externally applied direct current, that surface cannot be corroded and is therefore protected.

Diagram No. 3 illustrates the principle of cathodic protection. At the left is a simple galvanic cell, identical to Diagram No. 1. As shown, the anode would be eaten away while the cathode is unaffected. However, if another plate is inserted into the cell (Diagram 3—right) and connected to a power source externally as shown, then the new plate becomes the anode and both of the original plates become cathodes. The former anode is now cathodic and is no longer corroded.

In this system, two things are apparent. The potential (voltage) of the new power source must be greater than the natural potential of the cell itself, which is usually small. Also the new anode would eventually be destroyed—sacrificed to save the other surfaces. Such anodes are known as "sacrificial" anodes.

In the case of pipe lines, the pipe to be protected is connected by wire to the negative side of some direct current power source, such as a motor generator set or a rectifier unit, the positive side of which is connected to a so-called "sacrificial" anode, usually some sort of junk iron. The anode is buried in the ground at some distance from the pipe. Current coming from the power source passes first by wire to the anode, then through the ground to the pipe, returning by wire to the source. The pipe thus becomes negative to the anode and the latter is destroyed instead of the pipe. Hence the name "sacrificial." The cost of replacing the junk iron anodes is small, as is also the cost of power required.

In protecting the interior walls of steel tanks the tank is made cathodic and dc. current flows from the anode suspended in the tank, through the water and to the tank walls.

It must be understood that, while theoretically such a method should provide complete protection, due to the numerous uncontrollable factors encountered in the field the conditions causing corrosion can only be mitigated to a large extent. In any case, the life of the pipe line or tank is greatly extended and the cost of protection is well worth while.

Application and Arrangements

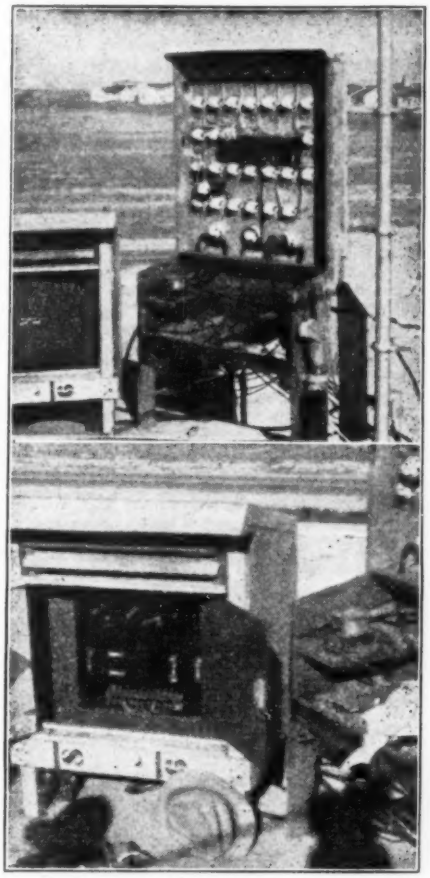
While there was no precedent to be followed in the case of a sewage digester, it was felt that the cathodic-protection scheme could be used to advantage, and would reduce, if not entirely prevent, the necessity of costly replacements in the near future.

Two anodes were provided, one being hung through each of the two manholes in the roof of the digester. These anodes were steel plates eight feet long, two feet wide, and one-quarter inch thick, suspended by two one-inch diameter iron rods welded to the plates and supported from wooden frames in the manholes. The iron supporting rods were later found to be badly attacked and were replaced by two-inch by four-inch redwood hangers. The hangers were long enough so that the plates hung vertically in the upper zone of sludge, with the tops about two feet below the surface. Heavy copper cables protected with heavy rubber covers were connected to the plates and carried out of the manhole and across the roof to the central platform of the digester.

A Westinghouse "Rectox" rectifier (see Fig. V), connected to the lighting circuit, provided direct current. The two anode cables were connected to the output or positive terminals of the rectifier. The return or negative terminals were connected to the main bus of a test panel.

In order to provide for definite return paths for current from the various parts of the tank, individual wires were connected to these parts and brought to the test panel. Connections were made to the hot water pipes at three points outside the tank, to all sludge and other piping, to the steel beams supporting the roof, to eight points in the steel reinforcement, to the driving machinery and by sliding brush contacts to the upper part of the stirring mechanism. In all, thirty-two such connections were made, each with its individual wire to the test panel.

The test panel (see Figure IV) consisted of a sheet of "masonite," about five feet high and thirty inches wide, in the center of which a brass bus plate was fastened. Mounted on the panel were thirty-five polarized porcelain receptacles, one for each return wire, one for each anode cable and one for the main return to the rectifier. Each return receptacle was fitted with a homemade shunt, of three ampere capacity, across the terminals and on one side was connected to the main bus plate. Each return wire was connected to its respective receptacle and correctly labeled. Twenty-five ampere shunts were fitted across each anode cable receptacle, and a fifty ampere shunt was fitted across the main return receptacle.



Figures IV and V—Cathodic Protection Equipment

(Above) Test Panel, With Metering Receptacles, Shunt sand Ammeters. On Left Is the Rectifier Which Converts Alternating to Direct Current. (Below) The Compact Westinghouse "Rectox" Copper-Oxide Type Rectifier in Temporary Housing.

Two ammeters were provided, each with cords and polarized plugs attached, one ammeter reading to three amperes positive or negative, the other reading to one hundred amperes, positive.

Diagram No. 4 shows the schematic arrangement of the various parts of the protective system. For simplicity, only four of the return connections are shown. The supply circuit to the rectifier is not shown. The supply is 120 volt, 60 cycle, A.C. current, only about 60 watts of energy being used all told.

When the apparatus is in operation the circuit is as follows: Current leaving the rectifier passes through the anode shunts to the anode plates. Thence it passes into the sludge, and through it to the hot water coils, stirring mechanism, reinforcing steel and other metal parts. From these parts it goes by the individual return wires to the receptacles on the test panel, and through the

shunts to the bus plate. From the bus plate it passes through the main return shunt to the rectifier.

The purpose of the shunts is to provide for measuring of the current without interrupting the circuit. The anode shunts permit the current passing to each anode to be measured separately. The individual shunts permit measurement of the current returning from each part of the tank to be protected. The main return shunt provides for measurement of the total current returned and serves as a check on the other readings. The readings on the individual returns permit these circuits to be balanced in approximate proportion to the area to be protected, and also indicate whether the connections are in good condition.

The Westinghouse rectifier has a capacity of 30 amperes at 3.2 volts, direct current, and is so designed that several combinations of voltage and amperage may be obtained. However, experience dictates that those tappings which produce 20 amperes at 2.2 volts should be used; and, thereby, the total power used is only that required for a medium size electric light. One-half the current is sent to each anode and the return circuits are balanced to carry from 0.25 to 1.5 amperes each. Readings are made and recorded periodically to note changes.

The Anodes

The steel-plate anodes are hoisted out for inspection from time to time and are replaced as needed—(see Figure VI). When removed, the plates are found to be covered with a black honeycombed crust about two inches thick, while underneath the crust the plates are deeply pitted and eaten away at the edges. The wooden hangers are not affected, nor does the crust seem to affect the operation of the plate as an anode. One pair of plates, originally weighing 195 pounds each, were found to weigh 90 pounds each, after fourteen months of service. Each plate lost, therefore, 105 pounds or 7.5 pounds per month. This equals approximately 9 pounds of iron per ampere per year. Figure VII shows the condition of an anode, after final removal. This plate has been left in service too long. It is probable that the anodes should be replaced after nine to twelve months' service at the Terminal Island plant. At other plants the service period per anode may be longer or shorter, depending upon local conditions.

The cost of the installation was about $200.00, of which $140.00 was for the "Rectox" rectifier. This cost does not include labor, which was done by the plant operators, under the supervision of the writer. It is indicated that anode replacements will cost $10.00 to $15.00 per year, depending on conditions. The power cost is truly negligible.

Most of the anti-galvanic cathodic protection equipment was put in operation about the middle of December, 1938, using a home-made motor-generator set for power supply. The "Rectox" unit was purchased and installed later.

Results

It is unfortunate that no definite information can be given at this time as to the results of this method of protection, as no opportunity has occurred to make a complete inspection of the interior of the digester. Three things, however, seem to indicate that the protection has been effective.

First: On May 5, 1939, after about five months of operation, an inspection was made of the scum and upper mechanism in the digester, and the previously attacked parts of the scum breaker truss were found to be in excellent condition, the "Bitumastic" coating being intact. This indicated that no noticeable corrosion was taking place in this part of the merchanism.

Second: If the corrosion had continued at the alarming rate that it had during the first fourteen months, it seems highly probable that some of the structural parts of the mechanism would have failed entirely in the nearly two years of operation since the protection was installed.

It was gratifying to note that, when for test purposes, the rectifier was shut off, the current in certain of the individual return circuits immediately reversed. This was exactly what was to have been expected from the results of the experiments with the "pot" model, indicating that the conclusions drawn therefrom had been correct. It also indicated what might have been expected if anti-galvanic protection had not been applied. Further than that, it indicated that all spots could not be reached with the protective coating applied to the metal parts in place.

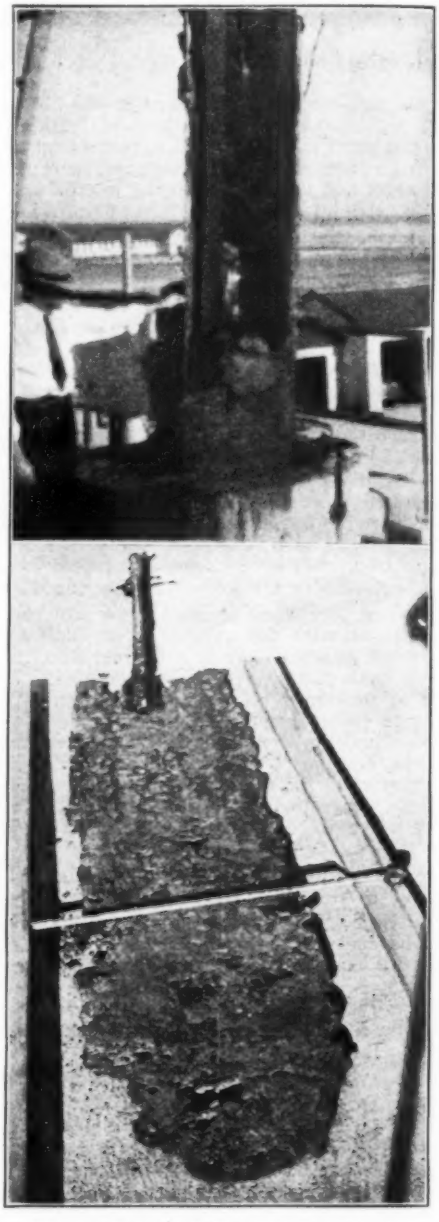
In the near future it is planned to install new sludge mixing equipment and new vertical type heating coils in the digester, to convert it into the first stage of a two-stage system, which will involve use of the decantation tanks as secondaries. When the tank is emptied for this work, a complete inspection will be made. It is our intention to make the results of this inspection and subsequent opinions, or changes in procedure, public at a later date.

In the meantime, the writer hopes that others will interest themselves in the matter of possible electrolytic corrosion, not only in digesters, but in other units of treatment plants as well.

Acknowledgments

The writer is indebted to Mr. Otto Wiemer, earlier mentioned in this paper, for his assistance in the field and laboratory and the solution of the problem was in a large measure due to his wide knowledge of the fundamentals of electrolysis and electricity in general. The plant operators, particularly Mr. Fiscus, Chief Operator, deserve praise for their help and ingenuity in solving many problems of application.

The Terminal Island Sewage Treatment Plant is part of the sewer system of the city of Los Angeles, California, and is operated under the Board of Public Works. Mr. Lloyd Aldrich is City Engineer. Mr. H. G. Smith is Engineer of Sewer Design and the writer was, at the time of these investigations, Assistant Engineer in charge of plant operations.



Figures VI and VII—The Inexpensive Sacrificial Steel Anode

(Above) Hoisted Out for Inspection. Note Crust Adhering to Plate. (Below) An Anode After 14 Months of Service; Little Being Left But Metal Lace and Wood Frame. Frame Strips Show Original Size of Anode.

P.F.T. Pacific Flush-Tank Co.

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SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

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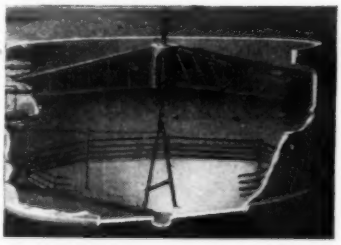

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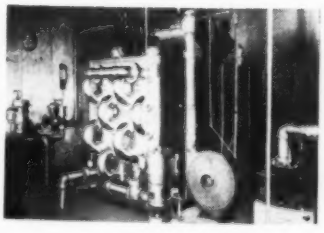

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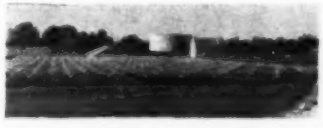

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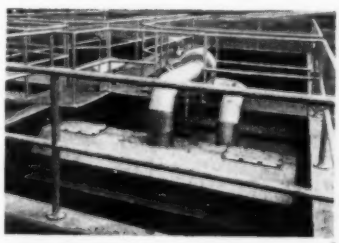

have three applications. (1) Supernatant liquor treatment; essentially an aerator settling tank unit which returns to the head of the plant a treated effluent which will not cause operating difficulties. Bulletin 142. (2) Pre-treatment of laundry and trade wastes; as a combination aerator-settler unit which reduces grease content, suspended solids and B.O.D. Bulletin 141. (3) Pre-aeration and grease removal; consists of a surface chamber to which a vacuum is applied as a means of mixing atomized liquids and solids with a large volume of free air. Unit is mounted in a small section of the primary clarifier. Bulletin 140.

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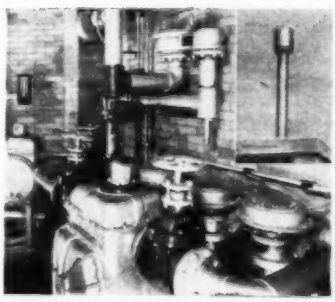

Consists of Flame Traps, waste gas pressure relief flame traps, waste gas burners, pressure gauges and other boiler room and accessory equipment designed to eliminate explosion hazards and to insure constant pressures. P.F.T. Flame Traps have renewable elements which permi passage of gas but not flames. Valve in line is closed when heat is sufficient to melt fusible plug. All described in Bulletin 121-A.

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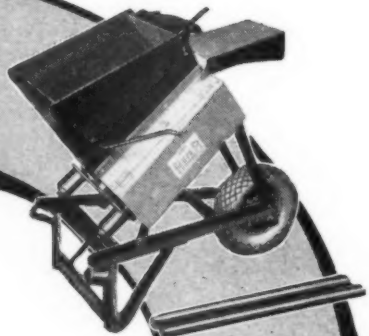
ROYER Jr. Sludge Disintegrator, gasoline engine driven.



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One man serves hopper while Royer further dries, aerates and reduces sludge and piles or loads in one operation. Model "NSB-4," electric powered, at Colton, Calif., sewage works.

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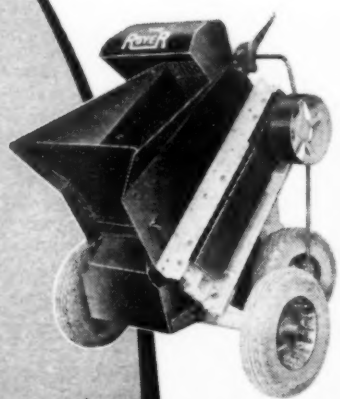


ROYER "NSM-2" Sludge Disintegrator, with belt-to-tractor drive.

FERTILIZER AND FERTILITY VALUES OF SEWAGE SLUDGE

WILLEM RUDOLFS, Ph.D.
Chief, Dept. of Water and Sewage Research
N. J. Agricultural Experiment Station, New Brunswick, N. J.

THE use of various types of sewage sludge as sub-grade fertilizer or soil builders has been advocated for many years. Enthusiasm to use this by-product of sewage treatment has come mainly from the layman, but soil technologists and soil scientists continue to wonder why sludge is not returned to the soil for its plant food and fertility value. (Note that a distinction is made between plant food content and fertility value.) Many farmers, gardeners, florists and green-keepers have tried the material, but frequently have stopped after some years.

Sanitary engineers in general have looked at the sludge problem as a question of destruction of noxious matters rather than conservation of values. Sewage plant operators have tried to stimulate its use. There is an increasing tendency to find ways and means to utilize sludge, principally as a fertilizer filler or for soil improvement through direct application.

An inquiry to determine why the material is not used on a larger scale, especially from smaller plants, or why the use has been discontinued, seems to indicate several reasons which can be summarized as follows: (1) Insufficient knowledge of the value; (2) improper use of the material or insufficient preparation; (3) excessive claims made by the seller, or (4) lack of interest by the seller.

From a hygienic standpoint there is *no problem* if the sludge is used in a proper manner. A rather extensive inquiry made to determine whether ill-effects have been observed on animals or human beings, shows that where land disposal has been practiced for many years no disease or epidemics have occurred. This is probably due to the fact that users of large quantities of sludge have taken proper precautions. As a rule fresh sludge has been used only on forage crops and plowed under after application. Heat dried activated sludge and heat dried digested sludge appear to be safe for any reasonable use in agriculture, horticulture or floriculture, while well digested air dried sludge appears to be as safe as manures.

What Is the True Value of Sludge?

Determinations of the values in sewage sludges have chiefly been a matter of testing for the principal fertilizer ingredients (nitrogen, phosphorus and potash), while sometimes the organic matter content is taken into consideration. Users of sludge for agricultural or horticultural purposes have repeatedly called attention to the fact that the results obtained could not be entirely accounted for by the mineral or plant food constituents. The better results have been variously explained on the basis of: (1) The organic matter content of the sludge results in an increased moisture holding capacity of the soil, preventing retardation of growth or wilting during dry weather; (2) an improvement in the soil structure, especially in clay allowing more air to enter and subsequently a stimulation of oxidation or organic matter by the soil organisms; (3) introduction of large numbers of bacteria and protozoa, resulting in a speeding up of decomposition, the introduction of micro-organisms, such as molds, into the soil, making the nutrients more available for the plants; (4) introduction of certain minerals needed for plant growth; absence of weed seeds, which may utilize the available plant food.

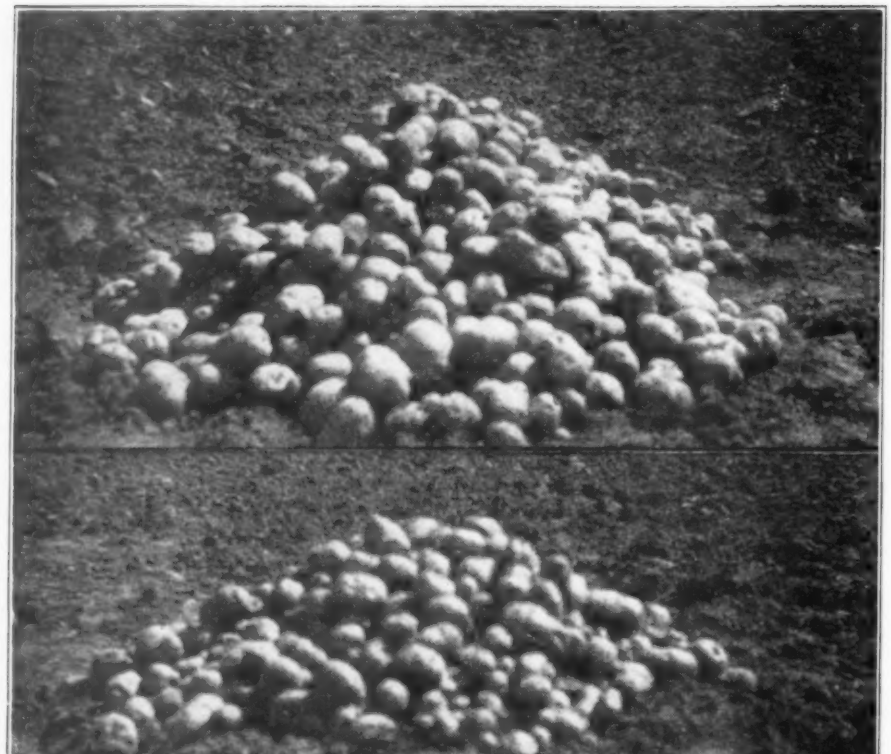
On the other side of the picture is the discontinuance of the use of sludge after several years on account of plant injury. The reasons advanced for plant injury have been mainly: introduction of poisons in the soil which were present in the sludge (certain industrial wastes); high grease content resulting in water logging and production of organic acids; burning of plants resulting from acidic decomposition products which make the soil acid.

Sludge Constituents—Major and Minor

Until a relatively short time ago it was assumed that only ten chemical elements (nitrogen, phosphorus, sulfur, calcium, magnesium, potassium, iron, carbon, hydrogen and oxygen) were indispensable for the growth of higher plants. Many other elements, if found effective, were regarded as plant stimulants. In 1914 Prof. Mazé at the Pasteur Institute in Paris showed that other elements were necessary. Not much attention was paid until in 1923, when Miss Warrington at the Rothamsted Experiment Station in England found that boron was essential for beans and several other plants. Only during the last few years has it been found that a number of plants can not complete their growth cycle without minute quantities of boron, copper, zinc, manganese, possibly molybdenum and several others. These "minor," or "accessory," or "micro-nutrient" elements have a remarkable effect on various phases of plant growth. Iron, for instance, plays a role in oxidation, copper has been reported as essential in certain oxidase systems; manganese is essential to respiration and to nitrate reduction in plants; zinc may be important in the change of carbonic acid to water and CO_2; certain metal deficiencies produce chlorosis of varied types of green plants.

A compilation of the chemical composition of sludges, including the main fertilizer constituents and the "minor" elements, is given in Table I. For comparison it should be kept in mind that the average fertilizer ingredients of barnyard manures are about 2 per cent nitrogen, 1 per cent phosphorus

Preparation and Conditioning Is Important to Marketing
For ease of handling and saleability compare the lumpy product on the left as removed from sludge drying beds with the uniformly granulated and aerated product turned out by a well-known sludge disintegrator.



A Potato Crop—With and Without

From the same area, in a field side by side, potatoes (above) were fertilized with 400 lbs./acre of Toledo's air-dried digested primary sludge, marketed under the name "Tol-e-Gro." The yield was just 200 per cent more than the pile (below) not fertilized.

(P_2O_5) and 1.5 per cent potash (K_2O). It is evident that in addition to the main fertilizer ingredients, small quantities of "minor" elements are present in the sludge which may play an important role in plant growth. The quantities of minor elements are relatively small, so that danger of poisoning the soil is absent. The quantities of lime salts present in the sludge varies with the hardness of the water supplies and the manner of sludge treatment. The amount of lime salts expressed as (CaO) may be as low as 2 per cent and as high as 12 per cent on a dry basis.

Humus Value

As a soil builder the humus content of sludge is less than that of barn-yard manure, because the ash content is greater, but still is of considerable value in sandy and heavy clay soils.

The crude fiber (cellulose, lignin, etc.), being complex insoluble carbohydrates, resist bacterial decomposition and remain longer in the soil (Table II). Most of the so-called total organic matter gradually disappears, but is of importance from the standpoint of humus accumulation and moisture holding capacity of the soil. Soils which retain a higher moisture content usually support a greater variety of plants and allow the plants to continue their growth even during dry spells.

Fats and greases are important chiefly because they make the sludge lump and interfere with the desirable uniform distribution of the sludge. Also, because grease decomposition produces acidic compounds, resulting in acidic soils. It is our experience that most of the injurious effects that may be chargeable to sludge application for a number of years are due to the accumulation of acids in the soil. The first few years these acids have a tendency to make insoluble plant foods present in the soil more available, hence produce better results than might be expected from the sludge alone. After a few years the available insoluble plant food has been reduced and the soil becomes more and more acid. Certain plants, which desire a neutral or only slightly acid soil, are retarded in their growth and finally are injured by the accumulated acidity. The simple application of agricultural lime (carbonate of lime) neutralizes this acidity. For best results in the long run, a judicious lime application every 3 or 4 years prevents a good deal of trouble. The fact that this simple remedy often has been overlooked accounts for reluctance of farmers and greenhouse growers to use sludge after a few years' trial.

Growth-Promoting Substances

Increasingly it is recognized that plants do not synthesize vitamins or their precursors as a philanthropic act for the benefit of animal or man. These substances have a function in the plant itself. The substances are generally classified as growth-promoting substances, since they may induce root development, stem elongation, cell swelling, ripening of fruit, stimulate germination and flowering, and produce other responses. Farm yard manure and decaying vegetable matter have been shown to contain various growth-promoting substances. Tests made for the presence of some of these substances in sewage sludges are summarized in Table III.

The quantities of growth-promoting substances required to affect the growth of plants are extremely small. Comparatively large applications of artificially produced compounds may even cause injury or retardation. Indole and skatole derivatives appear to be among the most effective growth-promoting substances. Indole and skatole, as well as butyric, acetic and propionic acids, are produced during decomposition of sludge and can be expected to be present. The presence of various growth-promoting substances gives to sludges a higher *fertility value* than indicated by a mere chemical analysis, which reveals only the principal *fertilizer ingredients.*

Practicing farmers have maintained for years that mineral fertilizers "burn out" the soil. What is meant is that mineral

TABLE I

Average Chemical Constituents of Sewage Solids and Sludges*

Element	Fresh Solids	Digested Sludge	Activated Sludge
Total Nitrogen (N)	4.50*	2.25*	6.20*
Phosphoric (P_2O_5)	2.25	1.50	2.50
Potash (K_2O)	0.50	0.50	0.75
Silica (SiO_2)	13.80	27.60	8.50
Iron (Fe_2O_3)	3.20	6.00	7.20
Aluminum (Al_2O_3)	2.10	4.30	3.20
Calcium (CaO)	2.70	5.70	1.70
Magnesium (MgO)	0.60	1.00	1.40
Manganese (MnO)	0.02	0.04	0.03
Sodium (Na_2O)	0.80	1.50	1.00
Titanium (TiO_2)	0.06	0.10	0.08
Copper (CuO)	0.02	0.05	0.05
Barium (BaO)	0.05	0.10	0.06
Zinc (ZnO)	0.01	0.04	0.03
Lead (PbO)	0.10	0.20	0.20
Nickel (NiO)	...	...	0.005
Cobalt (CoO)	0.0002	...	0.0002
Sulfur (So_3)	1.2	2.5	2.90
Chlorides (Cl)	0.50	0.50	0.50
Chromium (Cr_2O_3)	...	...	0.20
Arsenic (As_2O_3)	trace	trace	0.013
Boron (Br_2O_3)	...	...	0.0115
Iodine (I)	...	...	0.001

*All figures being % of each ingredient on the dry basis.

TABLE II

Composition of Sludges

Constituent*	Fresh Solids	Digested Sludge	Activated Sludge
Organic Matter	60-80*	45-60*	65-75*
Total Ash	20-40	40-55	25-38
Insoluble Ash	17-35	35-50	22-30
Pentosans	1.0	1.50	2.10
Grease and Fat (Ether)	7-35	3.5-17.0	5.0-12.0
Hemicelluloses	3.2	1.6	...
Cellulose	3.8	0.6	7.0†
Lignin	5.8	8.4	...
Protein	22-28	16-21	37.5

*All figures being % of each constituent on the dry basis.
†Includes lignin, etc.

TABLE III

Presence of Growth Promoting Substances in Sludges (Relative Amounts of Single Substances)

Substance	Fresh Solids	Digested Sludge	Activated Sludge
Skatole, ppm.	1.2 -7.8	traces	none to traces
Indole, ppm.	0.12-70	0.5-1.0	0.0-0.05
Ascortic acid (Vitamin C)	++++	++++	++++
Carotene	+++	++	+
Tryptophane (free)	++++	+	++
(combined)	++++	++	+++
Tyrosine (free)	++++	+	++
(combined)	++++	++	+++
Phenyl compds.*	++++	++	++
Naphthyl Compds. †	—	—	—

*As benzoic acid; † as α-naphthol.

fertilizers stimulate the destruction of organic matter, making the plant food, plant stimulants and hormones available in greater abundance. This results in increased crop yields, but also gradually reduces the stored-up fertility of the soil. Thereby the soil becomes poorer. The value of farmyard manure is in replenishing the organic matter, "minor" elements and growth-promoting substances. Its application is of importance, therefore, in making the soil gradually richer. A similar function can be ascribed to sewage sludge. Since sewage sludge contains only relatively small amounts of the principal fertilizer ingredients crop yield cannot be as great as from mineral fertilizers, but, like other improved animal manures, it improves the soil and will continue to do so if acidity is checked by lime applications.

TABLE IV

Crops and Plants Which Have Benefited From Sludge Applications

Truck crops—	Field crops and fruits—
Squash	Corn
Tomatoes	Wheat
Turnips	Rye
Pumpkins	Barley
Beets	Turnips
Carrots	Grass
Radishes	Beets
Parsnips	Mustard
Onions	Potatoes
String Beans	Tobacco
Lima beans	Cotton
Lettuce	Apples
Spinach	Citrus fruits
Sweet corn	Strawberries
Cabbage (and others)	
Trees and shrubs—	
Maple	Berberis
Ash	Spirea
Birch	Daphne
Chestnut	Cotoneaster
Prunus	Taxus
Cornus	Several broad leaf evergreens
Jasminium	
Hydrangea	
Flowers—	
Roses	
Carnations	

(Many annual flowers respond to sludge, in some cases leaf growth is more stimulated than is flowering.)

Sludge Enrichment or Sludge Filler

The addition of mineral fertilizers to enrich sludge results in a more complete product. Not only are the necessary major plant foods present, but the required "minor" elements and growth-promoting substances are available. This combination produces a balanced fertilizer and also a soil builder. This balanced product gives higher crop yields without loss of soil fertility. Such a balanced product is of especial value for sandy and clay soils. The response of rich loamy or peaty soils to this balanced product should be less and it explains partly why experiments conducted with various crops in different soils may appear to be contradictory.

The amount of organic matter present is of importance, because of its favorable effect on the absorption capacity of the soil, and is of further interest because it is the carrier for organic nitrogen, which aids bacterial decomposition and becomes available to the plant when needed.

Crops and Plants Benefited

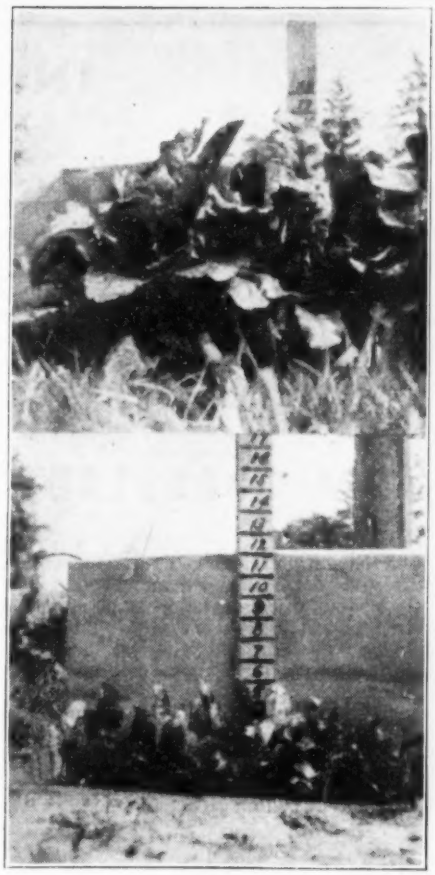
A compilation of plot experiment results and actual practice of crops and plants which have been benefited from sludge applications (Table IV) indicate that a number of grasses, root and leaf crops, trees and shrubs respond to sludge. The list is incomplete, because only those plants have been included where sludge was of *definite* value. Cases where the value was doubtful or contradictory have been disregarded. Sludge has been found to be of particular value on lawns and greens. It does not cause "burning," but small applications of lime are necessary from time to time.

The amount of sludge applied varies with the crop. For field crops the application varies from 6 to 10 tons per acre, but additions up to 40 tons per acre have produced good results. A number of nursery men have reported good results with young trees and shrubs with sludge used in a manner and in quantities such as would be used if the material were barnyard manure.

Over-All Value

The *fertility* values together with the *fertilizer* value of sewage sludges may be summarized in general as follows:

In addition to relatively small amounts of the principal fertilizer ingredients, sewage sludge contains "minor" chemical elements and growth-promoting substances essential and necessary for proper plant growth. It prevents depletion of humus and is capable of increasing the fertility of the soil. It improves the soil structure in general and increases the water-holding capacity of sandy soil in particular. The value of sludge is not the same for all soils, neither is it the same for all crops. Except for growth observations there is no adequate measuring-stick for revealing the over-all value of sewage sludges as soil improvers and growth promoters—in short, their fertility values as contrasted to their limited worth as fertilizers, based on the chemist's analysis alone.



40-Day Beet Growth Test
*Below—Only water applied—*100,000 *gal./acre/day. Above—Sludge liquid applied—*100,000 *gal./acre/day. Weight increases of roots alone,* 344 *per cent.*

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The chemical treatment of sewage and industrial wastes is an effective and economical method of increasing the efficiency of the ordinary sedimentation plant. Such treatment requires but little plant construction or capital investment. It provides a high overload capacity and flexibility in proportioning to produce the degree of purification required. Seasonal loads are readily handled with the Ferri-Cl_3or treatment.

Ferri-Cl_3or coagulates sewage and industrial wastes, thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that Ferri-Cl_3or is also an *economical* coagulant for sewage and a wide range of industrial wastes.

FOR COAGULATING SEWAGE

Ferri-Cl_3or provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

AMOUNT of Ferri-Cl_3or to be Used

The accepted procedure in determining the dose of Ferri-Cl_3or required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferri-Cl_3or and lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferri-Cl_3or stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for Ferri-Cl_3or. The amount in lbs. of Ferri-Cl_3or or lime required equals the number of c.c. used in the selected test x 10 x total sewage flow (m.g.d.) x 8.33.

FOR SLUDGE CONDITIONING

For efficiency and economy—ISCO Ferri-Cl_3or produces the best sludge floc for filtration, compared weight for weight with other commercial coagulants. Because of this fact, ISCO Ferri-Cl_3or is accepted as the lowest-cost powerful sludge coagulant on the market.

AMOUNT of Ferri-Cl_3or to be Used

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held, as in batch-mixing.

Various combinations of Ferri-Cl_3or and lime should be tested until the relative quantities for optimum operation are determined.

ISCO FERRIC CHLORIDE

The approximate quantities of chemical to be used in the plant can be determined from the laboratory test, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferri-Cl_3 or solution in gallons per 1,000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of lime in pounds per 1,000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

PREPARATION of Ferri-Cl_3or Solution

Saturated solutions of Ferri-Cl_3or are heavier than water, i.e.: you may have clear water above and undissolved crystals at the bottom of your mixing tank. Therefore, we recommend dissolving by one of the following effective and efficient methods:

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.

2. Mechanical mixing by (a) stirring, (b) air agitation, and (c) liquid recirculation.

3. Melting: Ferri-Cl_3or melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Cl_3or
Ferric Chloride
The FAST Coagulant
Ferric Chloride 60% ($FeCl_3$)

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CHEMICAL TREATMENT OF SOAPY WASTE WATERS

By HARRY W. GEHM*

Associate, Dept. Water & Sewage Research, N. J. Agr. Expt. Sta., New Brunswick, N. J.

WASTE Waters in which the polluting matter consists essentially of soaps are discharged in volume by laundries, scouring establishments, and synthetic rubber plants employing soap solutions in the polymerizing operation. Soap wastes are readily utilized by the bacteria responsible for self-purification in streams and those active in oxidation processes of sewage treatment; such wastes are generally high in oxygen demand. Experiments have shown that the rate of biological oxidation of soaps is essentially the same as that of domestic sewage. Pure soaps require almost twice their weight in oxygen for satisfaction of the five-day B.O.D., and commercial varieties, about one and one-half times.

In general, the economy of treatment of soapy waste waters (from the standpoint of equipment required, and of operation) dictates that they be segregated from extraneous diluting waters and be equalized so that a waste of relatively constant character be delivered to treatment units. Although rarely practiced, the first of these considerations holds great promise of lowered treatment cost and in many cases can be more or less combined with the second one, which has long been appreciated and practiced.

Treatment of such wastes with lime to obtain precipitation of a part of the soaps is a recognized procedure having been advanced by early English investigations[1]. It is at present used mainly as a method of pretreating laundry wastes prior to discharge into a sewage treatment plant for the purpose of reducing the loading. A number of investigators have published data demonstrating that removals of about 60 per cent of the five-day B.O.D. can be obtained in treating laundry waste water[2,3].

Treatment with Sea Water

Experiments conducted with laundry waste showed that the addition of waters rich in salts such as sea water, spent zeolite softener regenerant, and mineral well waters to such waste greatly enhanced lime precipitation[4]. Illustrative of the effect of these waters is the curve presented in Fig. 1 in which the effect of varied percentages of spent zeolite softener regenerant on lime treatment of laundry waste is shown.

Examination of this curve shows that B.O.D. removal in excess of 85 per cent could be obtained by addition of the mineral waters alone. Such treatment, however, is impractical because of the large quantity of light sludge formed, some of which settles and some of which floats. Addition of relatively small dosages of lime eliminated floating, producing a rapidly settling and a compact sludge.

Since the main salts contained in these waters are sodium, calcium, and magnesium chlorides and sulfates, some preliminary experiments were made to determine which salts were active in producing this effect. The first experiments were performed to determine the relative effectiveness of calcium, sodium, and magnesium salts in coagulating soaps. The effect of sodium chloride, in combination with the other salts, was also studied because the work with sea water and spent softener regenerant indicated that in such combinations sodium chloride might influence precipitation of the soaps.

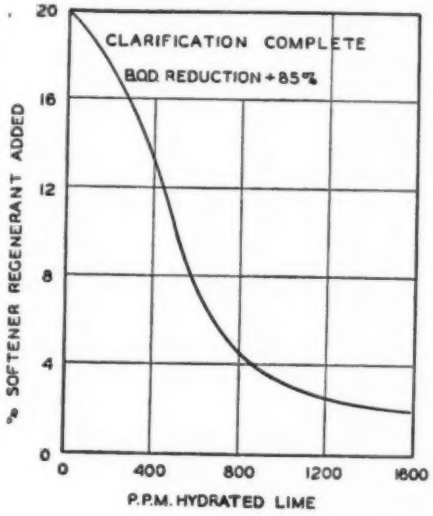

Fig. 1—Effectiveness of Spent Zeolite Softener Regenerant and Lime for Clarifying and Removing B.O.D. of Soapy Waste Water.

Effects of Calcium, Magnesium and Sodium Chlorides

A suspension of U.S.P. sodium stearate having a concentration of 1000 ppm. was prepared. To liter portions of this solution various dosages of magnesium chloride, calcium chloride, and sodium chloride solution and combinations thereof were added. All portions were stirred slowly for fifteen minutes after the chemical was added, to allow reaction to come to completion and assist in coagulation of the precipitated soaps. After settling, samples of supernatant liquor were removed from treated portions showing complete clarification. The five-day B.O.D. of these samples was determined using seeded and supplemented dilution water, and on a sample of the untreated suspension.

The percentage removals of B.O.D. were

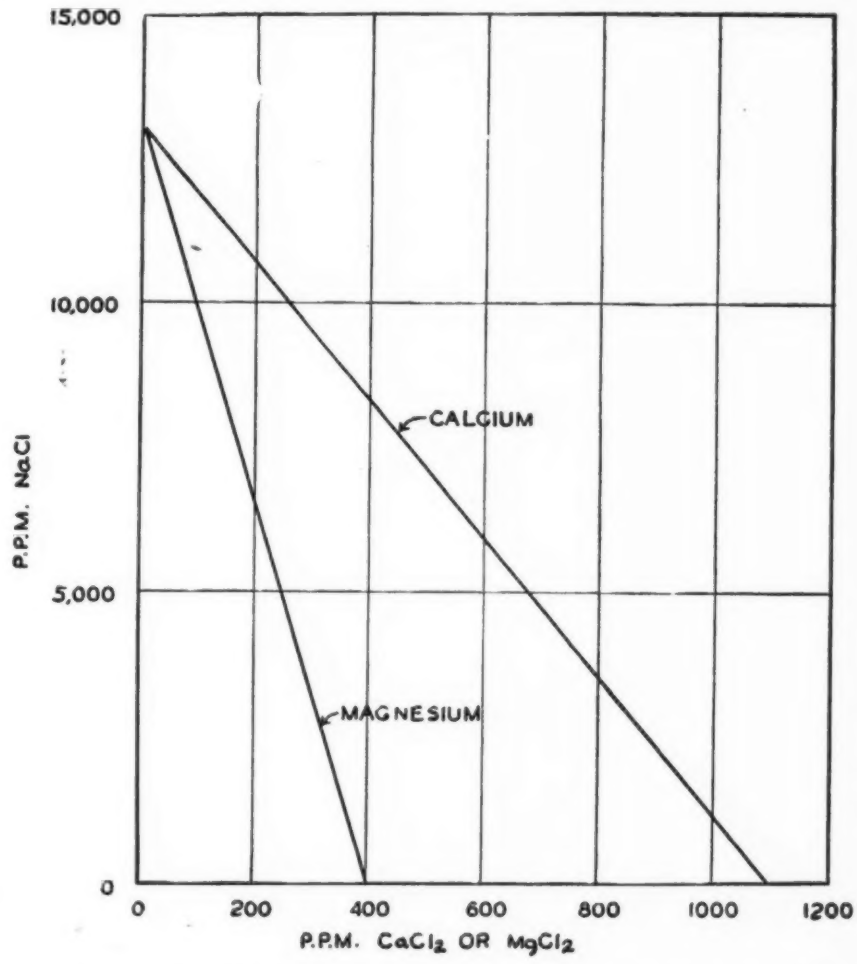

Fig. 2—Effectiveness of Calcium Chloride and Magnesium Chloride in Combination with Sodium Chloride in Reducing the B.O.D. of Sodium Stearate Suspensions.

*Now Technical Advisor, National Council for Stream Improvement, New York.

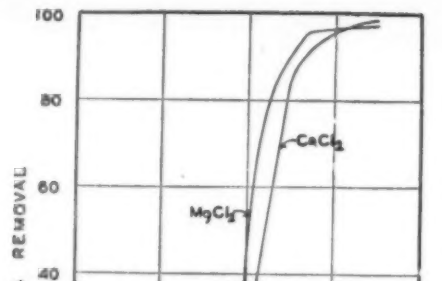

Fig. 3—Comparison of Calcium and Magnesium Chlorides for Reducing the Oxygen Consumed Value of Suspensions of Polymerizing Soap Waste.

calculated for all clarified samples and where removal was in excess of eighty-five per cent, the salt dosages employed were plotted. The resultant relationships established are shown in Fig. 2. Examination of the data obtained shows that per unit weight magnesium chloride is 2.7 times as effective in removing the soap as calcium chloride, and 32.5 times as effective as sodium chloride.

Relatively large dosages of sodium chloride did not alter the relative effectiveness of the calcium and magnesium salts, but increased soap precipitation due to its own action. For example, in samples where 5000 ppm. of sodium chloride was added 2.7 times the dosage of calcium chloride as compared to magnesium chloride was still required, and with a 10,000 ppm. sodium chloride concentration a similar relationship held. It appears, therefore, that the resultant removal of soap by combinations of sodium chloride and salts which react to form insoluble soaps is merely a summation of the salting out and precipitating reactions.

Treatment of Synthetic Rubber Polymerizing Soap

A sample of polymerizing soap waste was obtained from a synthetic rubber plant. The material was of the consistency of grease at room temperature. The bulk of this waste is removed from the reactors and recovered. The fraction remaining is washed out, producing suspensions of varied concentration. For experimental purposes suspensions of the waste in tap water were prepared. The general procedure of treatment consisted of adding coagulants, in solution, to 500 ml. aliquots of waste suspensions, stirring at slow speed for 15 minutes and settling for 30 minutes. Oxygen consumed determinations were run on supernatant samples withdrawn after settling.

Calcium chloride, magnesium chloride, sea water, and spent zeolite softener regenerant were employed as coagulants. The zeolite reagent had these following contents:

$CaCl_2$—7,144 ppm.
$MgCl_2$—1,703 ppm.
NaCl—13,489 ppm.

Lime alone, lime in combination with calcium and magnesium chlorides, and acid wastes, including pickling liquor, were tried. None of these treatments yielded promising results. Lime alone had little effect when applied in reasonable dosages. When used in conjunction with calcium and magnesium chlorides, lime had little effect except to increase the quantity of sludge formed. Acids and acid salt requirements were found to be very high and the sludge produced failed to settle rapidly.

Calcium and magnesium salts and waters containing mixtures of these salts gave good results as far as clarification and sludge settling were concerned. In this respect, the synthetic rubber waste differed from soapy wastes and sodium stearate suspensions, which produce voluminous curds when such salts are added. A suspension of the rubber waste containing 6572 ppm. total solids produced about 50 ml. of a granular, rapidly settling sludge when treated to the optimum degree in this manner.

Reduction in Oxygen Consumed Value

Reduction of the oxygen consumed value in excess of 95 per cent could be obtained by treatment with calcium or magnesium chloride as shown in Fig. 3, and little difference in the relative effectiveness of the two salts was observed.

Similar results (Fig. 4) were obtained with sea water and spent zeolite regenerant. In these experiments the oxygen consumed value was used as the index of soap removal. The quantity of regenerant required for a given waste water will depend on its content of calcium and magnesium salts.

On the basis of the total solids concentration in the waste suspension, about

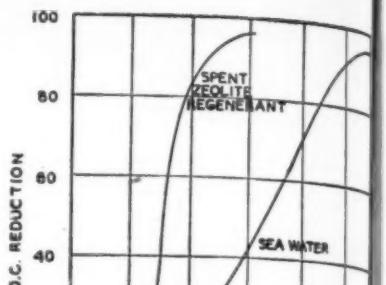

Fig. 4—Effectiveness of Spent Zeolite Softener Regenerant and Sea Water in Reducing the Oxygen Consumed Value of Suspensions of Polymerizing Soap Waste

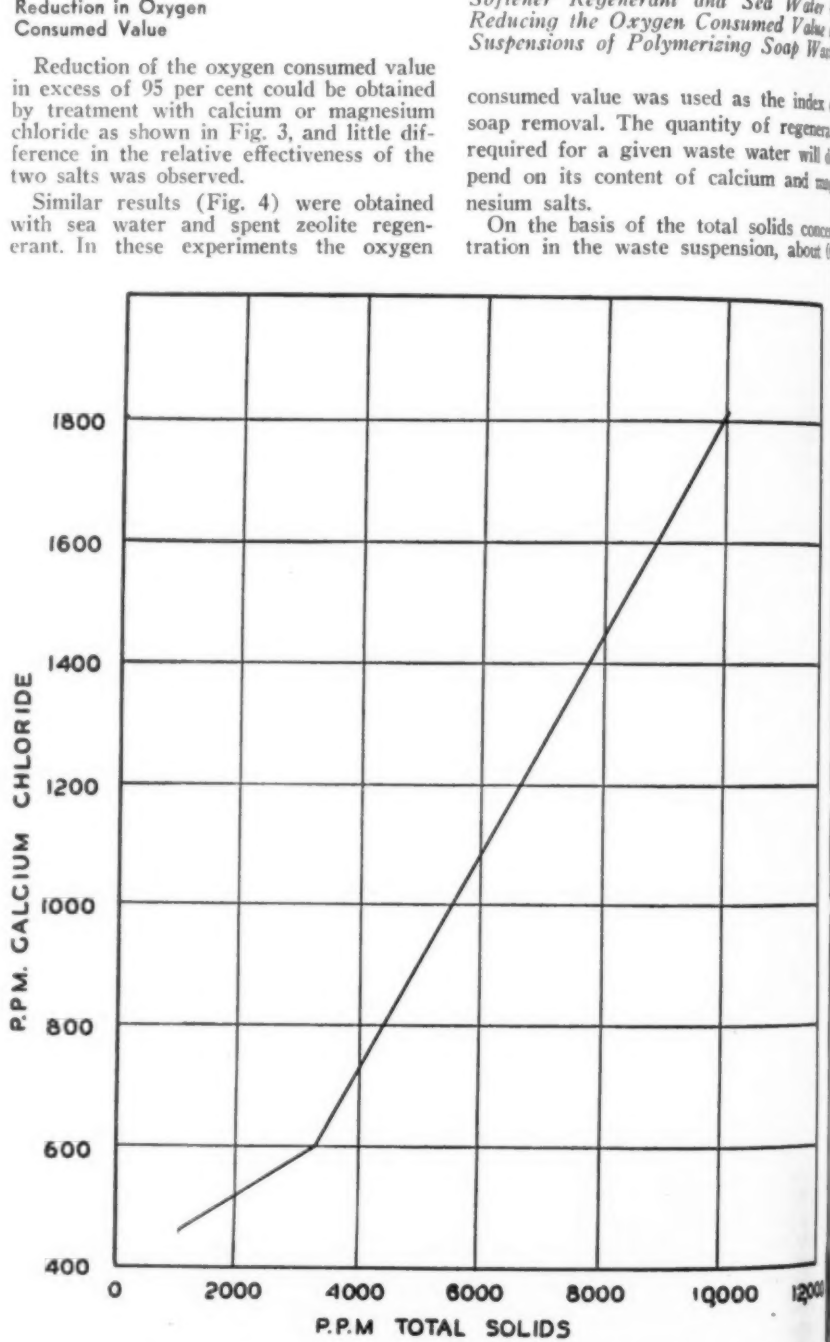

Fig. 5—Relationship Between Total Solids Content of Polymerizing Soap Waste Suspensions and the Quantity of Calcium Chloride Necessary for Optimum Precipitation

lb. of calcium or magnesium chloride would be required to precipitate, almost completely, one pound of solids from a waste suspension. In order to determine whether this relationship would hold over a wide range of concentrations, a series of the polymerizing soap waste suspensions of from 1,643 ppm. to 10,000 ppm. were treated with calcium chloride and the quantity necessary for optimum clarification was determined for each. Results of this experiment are plotted in Fig. 5. For concentrations of total solids between 3000 and 10,000 ppm. the relationship between solids and required calcium chloride for optimum treatment is linear and the relationship of 0.2 lb. of calcium chloride per pound of solids in the waste seems to hold. Lower solids concentrations require a higher salt to solids ratio.

Discussion

Suspensions of synthetic rubber polymerizing waste, consisting mainly of soaps, were found to react to various methods of chemical treatment, somewhat differently from laundry waste and pure soap suspensions. Of these differences, the most important of practical interest is the formation, in suspensions up to 10,000 ppm. concentration, of a granular, rapidly settling sludge on treatment with calcium and magnesium salts rather than the floating curds produced when other soap wastes are so treated.

The most economical of the methods of treatment investigated were the use of sea water, spent zeolite softener regenerant or calcium chloride. Magnesium chloride did not exhibit appreciably greater effectiveness than calcium chloride when added to this waste, whereas the magnesium salt proved more effective in the case of other soapy waste waters. About 0.2 lb. of calcium chloride was required per pound of total solids in polymerizing soap waste waters.

Oxygen consumed removals in excess of 95 per cent could be obtained by calcium or magnesium salt treatment. Such removals were accompanied by essentially complete clarification. A pound of total solids was found to consume 0.19 lb. of oxygen, on the basis of the oxygen consumed test. Comparing this value with the 0.2 lb. of calcium chloride required to treat one pound of total solids, the removal of oxygen-consuming matter is equivalent, on a weight basis, to the chemical dosage.

Sludge produced by calcium chloride treatment amounted to about one cubic foot per pound of solids treated, but could be thickened to a lesser volume. This sludge would lend itself to reclaiming and could be combined with the main volumes of waste which is so handled.

Summary

Experiments with soapy waste waters showed that treatment with sea water, spent zeolite softener reagent and mixtures of calcium and magnesium salts produced a high degree of clarification with the formation of a curdled sludge. Magnesium chloride was found most effective. Dilute soapy wash wastes from synthetic rubber polymerizing behaved somewhat differently in regard to chemical coagulation. Waters containing this waste can be treated to a high degree with calcium or magnesium salts or waters containing these salts. It was found that one pound of total solids required 0.2 lb. of calcium chloride, which removed 0.19 lb. of oxygen consuming equivalent present in one pound of waste. This treatment produced about one cubic foot of sludge, which could be thickened and reclaimed together with the concentrated wastes.

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(2) Kessler, L. H., and Norgaard, J. I., Sewage Treatment at Army Posts, *Sewage Works Journal*, 14, 757, (1942).
(3) Eliassen, R., and Schulhoff, H. B., Laundry Waste Treatment by Flotation, *Water Works and Sewerage*, 90, 418, (1943).
(4) Gehm, H. W., Volume Characteristics and Disposal of Laundry Wastes, *Sewage Works Journal*, 16, 571, (1944).

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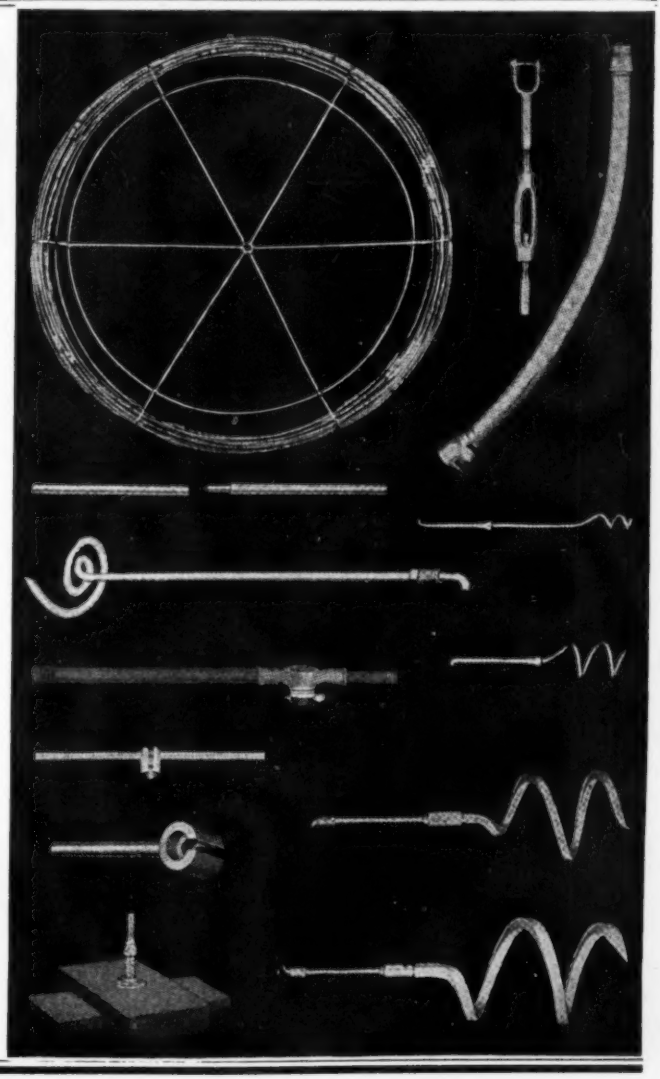

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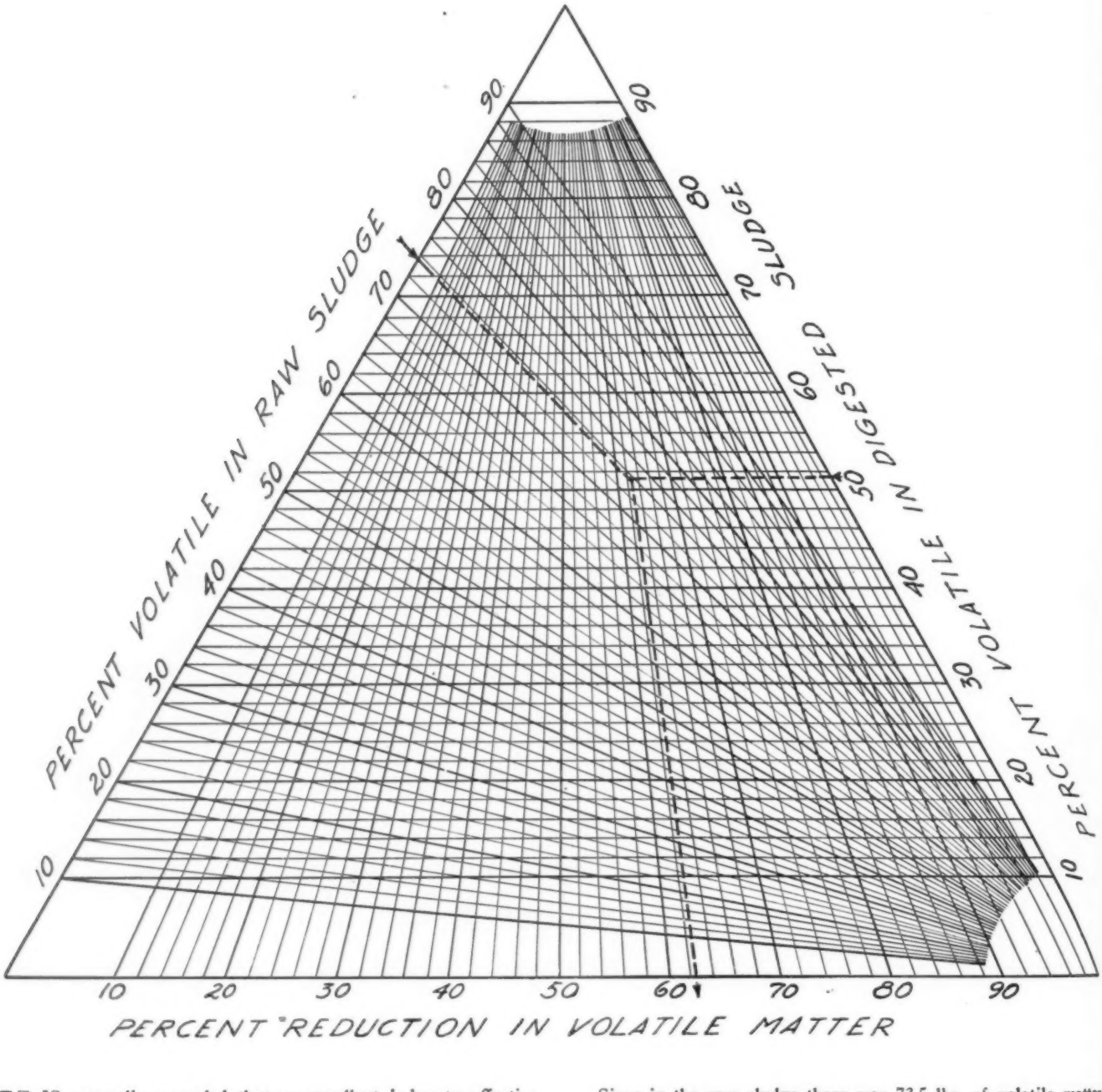
CHART FOR DETERMINING PER CENT SLUDGE DIGESTION

FRED H. BURLEY, Supervisor

Sewage Treatment Plant, Detroit, Mich



IT IS generally conceded that an excellent index to effective sludge digestion and efficiency of digester performance is the degree of conversion noted of the volatile matter in the sludge passing through the digesters. The degree of conversion is best expressed as per cent reduction of volatiles entering in the form of raw solids.

Volatile matter converted during anaerobic digestion is either evolved as gases or remains in the mother liquor (supernatant) as soluble organic or mineralized substances. The amount of gas produced is variously estimated at from 16 to 20 cu. ft. per pound of volatile matter converted.

The writer has found frequent computations of per cent reduction of volatiles on this basis to be a valuable check on digester efficiency, particularly so when considering the average figures for volatiles in the raw and digested products on the dry basis, from which the true reduction can be computed according to the following example. Assume:

	Volatiles	Fixed
Raw sludge	73.5%	26.5%
Digested	51.2%	48.8%

Since in the raw sludge there was 73.5 lbs. of volatile matter for every 26.5 lbs. of fixed solids, there was originally present in the raw sludge $\frac{48.8}{26.5} \times 73.5 = 135.4$ lbs. of volatile matter for every 48.8 lbs. of fixed solids. Therefore, the actual reduction is $135.4 - 51.2 = 84.2$ lbs. of volatile for every 135.4 lbs. entering as raw sludge. The reduction on a per cent basis is, therefore, $\frac{84.2}{135.4} \times 100 = 62.2$ per cent.

As a time-saver the accompanying chart was developed. It is simple to use. The arrows and dashed lines indicate the manner in which the per cent volatile in the raw and digested sludge (taking the above example) is located on two sides of the chart and the lines followed toward the opposite apex and parallel to the base, respectively, to their intersection. The line projected from this intersection to the base reveals the percentage reduction in volatile matter.

RAPID METHOD FOR DETERMINING SLUDGE SOLIDS

The Sludge Triangle Procedure

By GEORGE E. SYMONS and STEPHEN R. KIN
Chief Chemist *Assistant Chemist*
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THE Sludge Triangle Procedure is a rapid method for determining sludge solids. The theory, experimental development and results of this method are to be found in the Jan. '42 issue of *Water Works & Sewerage*. Certain facts drawn from the article are presented here:

1. It is possible, by use of a special "sludge triangle" graph, to estimate *any two* characteristics of a sludge if the volume of filtrate liquor from laboratory vacuum-filtration of a chemically treated sample, and *one* other characteristic, are known. These characteristics are per cent solids, per cent volatile matter and specific gravity.
2. The method for determining the solids content of a sludge depends on the treatment of a measured sample of sludge with known quantities of lime and ferric chloride, measurement of the volume of filtrate resulting from vacuum filtration of the treated sample, and determination of the specific gravity of the untreated sludge sample. It is possible to perform both tests in ten minutes, after which the total solids and volatile matter content may be estimated with a reasonable degree of accuracy through use of the graph known as the "Sludge Triangle."
3. The per cent solids content may also be estimated from volume of filtrate or specific gravity, if the approximate volatile matter content of the sludge is known. Or, the volatile matter may be estimated from the volume of filtrate liquor or specific gravity, if the total solids content is known. And, specific gravity may be estimated, if total solids and volatile matter content are determined.
4. This simple method is particularly advantageous in plants using chemical conditioning of sludge where the quantity of conditioning chemicals used is dependent to some extent on the volume of water associated with the sludge and/or its content of volatile matter.

Procedure

Filtrate Volume

Measure 200 ml. of well-mixed sludge in a 200 ml. graduate (calibrated to deliver 200 ml. volume of water). Pour the sludge into a 400 ml. beaker that has been rinsed with water and drained, but not dried.

Add 10 ml. of lime reagent containing 0.1 gram of available CaO per ml. Mix well with a flat policeman. Add 5 ml. of ferric chloride reagent containing 0.1 gram of $FeCl_3$ per ml. Mix again.

Place a No. 615 crepe surface filter paper, or equal, on a 3½ inch Buchner funnel, and insert the funnel in a 500 ml. filtering flask. Wet the filter paper with water, apply vacuum until the free liquid has been removed from the funnel, then empty the filter flask.

Pour the conditioned sludge into the Buchner funnel, using a flat rubber policeman to remove drops of the sludge sample adhering to the walls of the beaker.

Apply the vacuum to the flask. When the break-through of air is noted, carefully press the surface of the filter cake with the flat top of a mushroom stopper, or other flat object, in order to close the cracks in the cake and secure full effect of the vacuum. Maintain the vacuum and continue pressing the cake until the rate of passage of liquor through the Buchner funnel is less than one drop every five seconds. To continue the vacuum beyond this point may produce an evaporation of liquid sufficient to interfere with the accuracy of the test.

Pour the filtrate from the vacuum filter flask into a 200 ml. graduate (preferably the same as used in measuring the original sludge), and note the volume of the filtrate liquor.

Determination of Specific Gravity

For the determination of specific gravity use a 500 ml. Erlenmeyer flask (to reduce the error attendant with use of smaller samples). Into the neck of the Erlenmeyer flask insert a special rubber stopper (made of a No. 7 one-hole stopper and half of a No. 5 one-hole stopper, as shown in Fig. 1). Weigh on a laboratory torsion balance to the nearest 0.5 gram.

To determine the specific gravity, pour a well mixed sample of sludge into the tared Erlenmeyer flask and stopper it, forcing excess sludge out through the glass tube. Rinse the outside of the flask. Hold a finger over the end of the glass tube and shake the Erlenmeyer flask in a vertical plane with a rapid upward motion and a slow downward motion. This technique increases gravitational force and causes small bubbles, entrapped in the sludge, to rise to the top. After shaking about 50 times in this manner, remove the special stopper and add sludge to the flask until full. Replace the stopper in the flask and force out excess sludge. Wash the Erlenmeyer flask, wipe the outside and weigh. The weight of the sludge divided by the weight of the same volume of water required to fill the flask is the specific gravity.

Use of Sludge Triangle

Experimental study indicated the interrelation of all factors affecting the release of water from a chemically treated sludge; namely, per cent solids, per cent of volatile matter and specific gravity, as related to ml. of filtrate obtained from the sludge that had been treated as described above. The data, when plotted, produced lines within a wedge-shaped triangle. This graph, designated "The Sludge Triangle," is shown in Fig. 2.

The useful applicability of "The Sludge Triangle" depends on its accuracy when compared to the present standard method[2] of evaporating samples to dryness and weighing. To obtain such a comparison, the proposed method was run in parallel[1] with the standard method for a period of 28 days.

This comparative study indicated the average error in total solids by the new method to be only 0.02 per cent of the standard method. (This agreement is somewhat surprising since the proposed method actually determines the suspended and flocculatable solids, and does not include the dissolved solids in the expressed liquor. Total solids should be at least 0.1 to 0.3 per cent higher because of this dissolved matter.) In the estimation of volatile matter content, "The Sludge Triangle" is less accurate. The average error during the four-week period was 2.43 per cent, with wider variations in individual samples than in the case of total solids. It appears that the errors are greater when the concentration of solids is below 3 per cent.

These errors are based on the assumption that the standard method is correct. Considering the difficulties of sampling sludges for the determination of total solids and volatile matter (by evaporation and ignition), it is not surprising that there are some differences between the two methods. It has been shown that sampling[3] is important in sludges of this type.

Variations in Technique

(1) In special cases, it was found that certain variations in technique could be employed. For example, when the solid concentration is above 8 or 10 per cent, and a sample of sludge does not pour cleanly from a graduate in which it is measured, the graduate may be rinsed out with a 20 ml. of water from a pipette and the rinse water poured into the beaker containing the sludge to be conditioned and filtered. After the filtration, 20 ml. is subtracted from the volume of the filtrate readings in order to give the filtrate volume from the original sludge.

(2) When greater accuracy of measurements is desired, it is

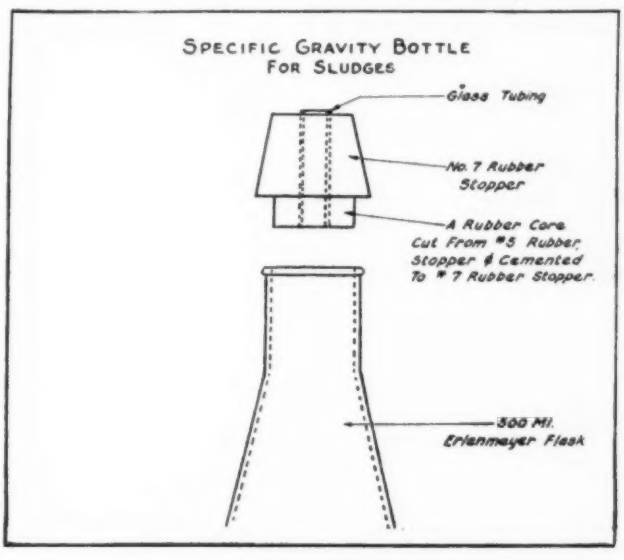
SPECIFIC GRAVITY BOTTLE
FOR SLUDGES
Glass Tubing
No. 7 Rubber Stopper
A Rubber Core Cut From #5 Rubber Stopper & Cemented To #7 Rubber Stopper
500 Ml. Erlenmeyer Flask

Fig. 1—Flask for Determination of Specific Gravity of Sludges.

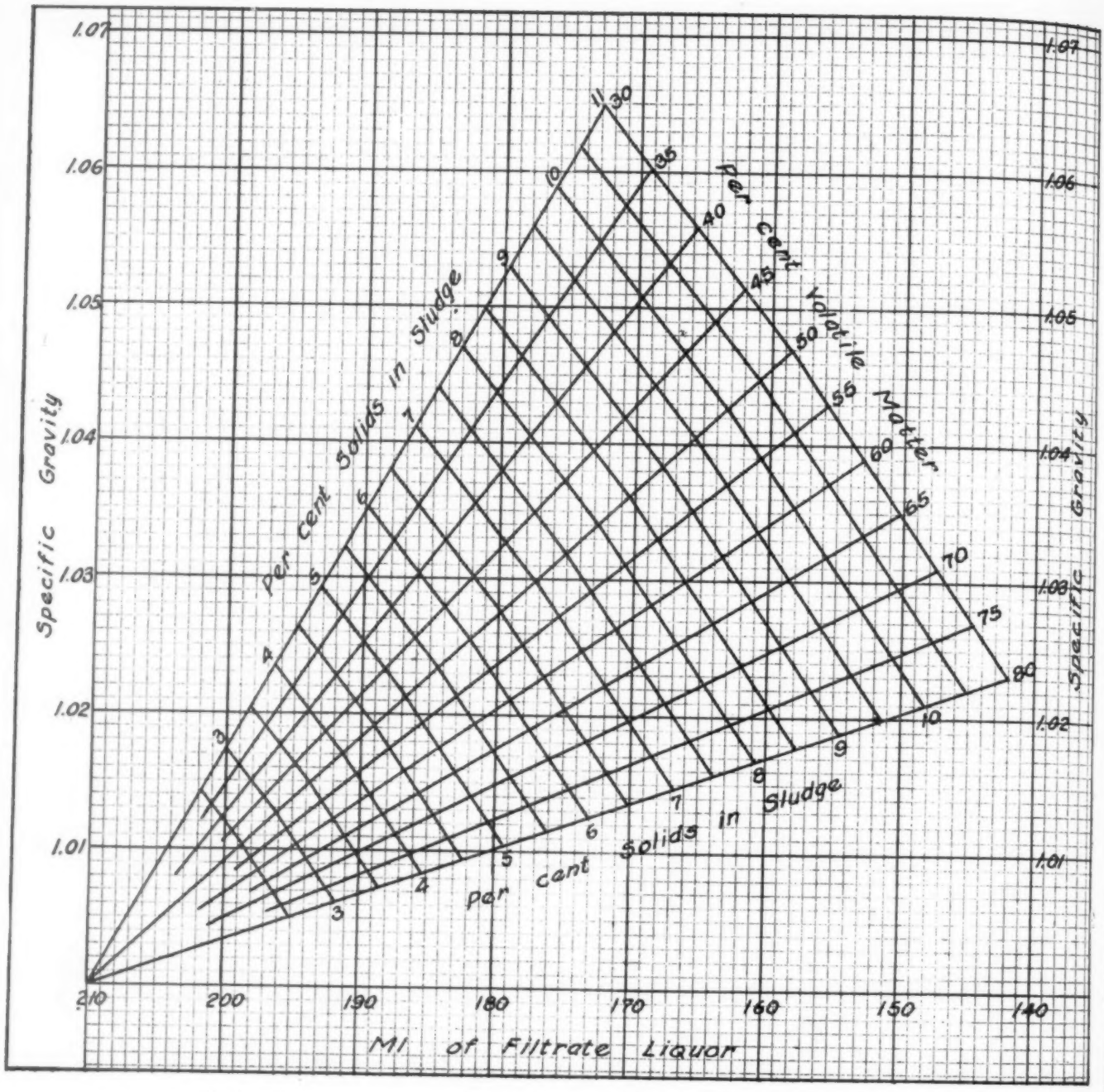

Fig. 2.—The Sludge Triangle. A Graph of Interrelations of Three Sludge Characteristics.

possible to weigh the original sample of sludge and then weigh the graduate or beaker from which it is poured into the Buchner funnel. This difference in weight when corrected for specific gravity will give the actual volume of sludge conditioned and filtered. Inasmuch as the test depends on the use of a standard 200 ml. sample, any variation from that volume, as determined by difference in weight, according to this method may be applied to the filtrate volume reading in order to produce a correct reading.

(3) For sludges of greater than 8 per cent solids, the gravity may be determined by diluting the sample with an equal volume of water. This procedure simplifies the removal of entrained air bubbles. In this case the specific gravity of the original sludge is calculated according to the equation:

$$(\text{Sp. G.} - 1) \times 2 + 1 = \text{Sp. G. of original sludge}$$

This technique will eliminate some of the objections to the determination of specific gravity cited by Smith.[4]

(4) To further simplify the technique, and increase the accuracy of the test, determine the specific gravity in a 200 ml. Erlenmeyer flask and use the sample thus weighed as the sample to be chemically conditioned and filtered. The gain in accuracy of determining the amount of sample filtered would offset the decrease in accuracy of the specific gravity determination on the smaller sample. (If the 200 ml. flask does not hold exactly that volume, the graph must be reconstructed.)

(5) If the volatile content of the sludge is not known, determine the specific gravity of the sludge and the volume of the filtrate liquor. From these, the per cent solids in the original sludge sample and the per cent volatile matter in the sludge may be determined from the graph. If the volatile content of the sludge is known, or approximately known, it may be unessential to determine the specific gravity in order to obtain the approximate concentration of solids in the sludge.

This particular "Sludge Triangle" was developed on raw and digested sludge from the Buffalo sewage treatment plant. Sludges from other sewage disposal plants may exhibit slightly different characteristics in this test and this "Sludge Triangle" therefore may not apply directly. A specific triangle may have to be developed for each particular type of sludge; this may be especially true for activated sludge.

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3. G. E. Symons and B. Morey, "The Effect of Drying Time on the Determination of Solids in Sewage and Sewage Sludges." *Sew. Wks. J.*, **13**, 936-39 (1941).

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PRINCIPLES OF POWER GENERATION WITH SEWAGE-GAS ENGINES

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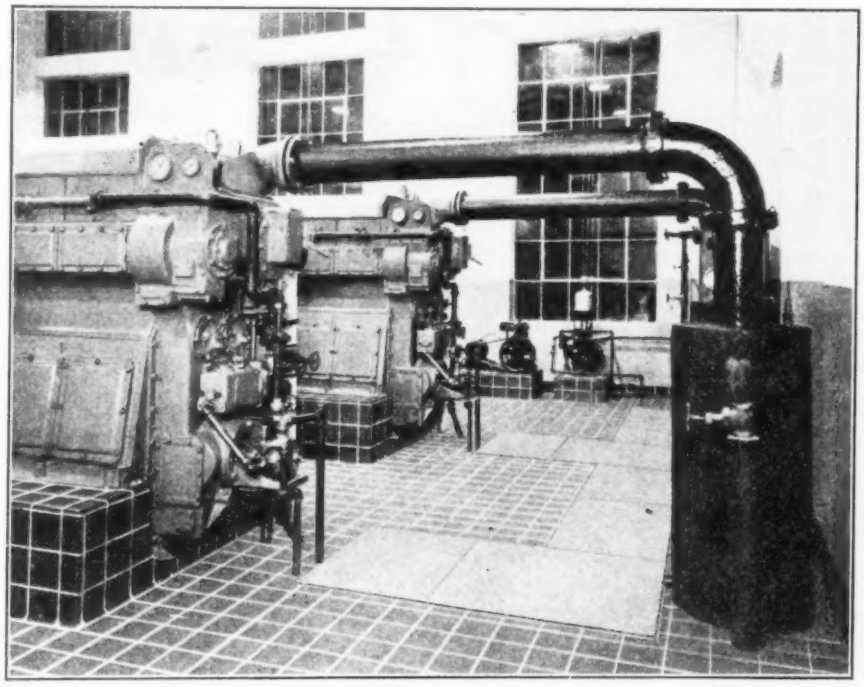
Many interesting accounts of sewage-gas engine power generating installations have been published in the engineering literature during the past several years. Several of these, particularly the articles of Walraven (1) and Sperry (2), in WATER WORKS & SEWERAGE and *Sewage Works Journal* have been outstanding in the technical thoroughness with which the authors discussed their experiences with this new and valuable adjunct to sewage treatment.

The writer has recently had occasion to make a comprehensive study of the feasibility of power generation with sewage-gas engines for the Sewage Treatment Works of the Rahway Valley Joint Meeting. The results of this study indicate that a very substantial saving in power costs is possible by the substitution of gas-engine generator sets for the present public utility power. Our current annual power bill is approximately $5,700.00, which covers cost of pumping all sewage entering the plant, power for all auxiliary pumps and mechanical equipment, and lighting.

It should be pointed out that the only justification for making a capital expenditure for power generating equipment to supplant outside power service must lie in the *net* annual savings in power costs which may be derived. The considerations for or against such an installation must be purely financial, as the self-generation of power will not add to, or detract from general sewage plant operation, or the results to be obtained from the treatment processes.



Twin 150 H.P. Cooper-Bessemer Engine-Generator Sets for Durham, N. C. Note waste heat boilers on right.

Arrangements Possible

Many arrangements are possible by reason of which the installation of sewage-gas engines may prove to be desirable. Some are as follows:

1. Engines direct-connected to sewage pumps where all or part of the plant flow is pumped.
2. Engines direct-connected to blowers used for aerating sewage.
3. Engines direct-connected to generators for generation of all or part of the electric power required.
4. Engines direct-connected to miscellaneous items of mechanical equipment.

This article will present the technical and economic phases of a complete power-generation plant designed to provide power for *all* the operating requirements of the Rahway Valley Sewage Treatment Works. While the Rahway Plant is a primary treatment plant having a capacity of 25 mgd, the type or size of plant does not in itself control the economics of sewage-gas power production. A number of factors influence the problem, and each should be thoroughly studied. They are as follows:

1. Experience at other sewage treatment plants where sewage gas power is being used.
2. Power requirements for the service desired—average and peak loadings.
3. Size and type of generating units required.
4. Standby power service.
5. Quantity and dependability of gas supply as compared to the average and peak power requirements.
6. Heat recovery for the heating of digestion tanks and buildings.
7. Probable first cost.
8. Annual interest and amortization charges.
9. Operating and maintenance costs.
10. Annual savings, if any, as compared to the present power costs.

Experience at Other Sewage Treatment Plants

It was first thought advisable to investigate the experience at other sewage treatment plants where gas engines are in use. Accordingly, questionnaires were sent to a number of sewage treatment plants which have been using sewage-gas power over varying periods of time. The information obtained from these questionnaires is tabulated in Table 1, and may be summarized as follows:

1. Three plants from which replies were received were larger than our plant, ten were smaller.
2. All showed a net annual savings. Some indicated that interest and depreciation were first charged off; the others did not clearly stipulate.
3. The annual cost of repairs as compared to power production in most cases is very low.
4. The annual cost of lubricating oil in most cases is very low.
5. In most cases, a statement was made to the effect that the engines were operated by the regular force, with no additional men.
6. Each reply indicated that sewage-gas generation of power is satisfactory and practical.

Power Requirements

The power requirements for a new plant must be estimated, but for a plant in operation with a back-log of operating records,

the present and probable future requirements can be determined with a fair degree of accuracy.

By an examination of the first three columns of Table 2 under the heading "Hourly Rates of Power Consumption," it can be seen that the hourly power demand during an average day for the Rahway Valley Plant approximated 40 KWH during the first ten months of 1938. The hourly average of a maximum day during this period was 114 KWH, while for a minimum day it was 23 KWH. Temporary demands higher than 114 KWH have been recorded on the local power company's demand chart, the highest being 124 KWH during a heavy storm in September. Such extreme peak demands, although not frequent, do occur occasionally.

From these records, the folowing power requirements were determined:

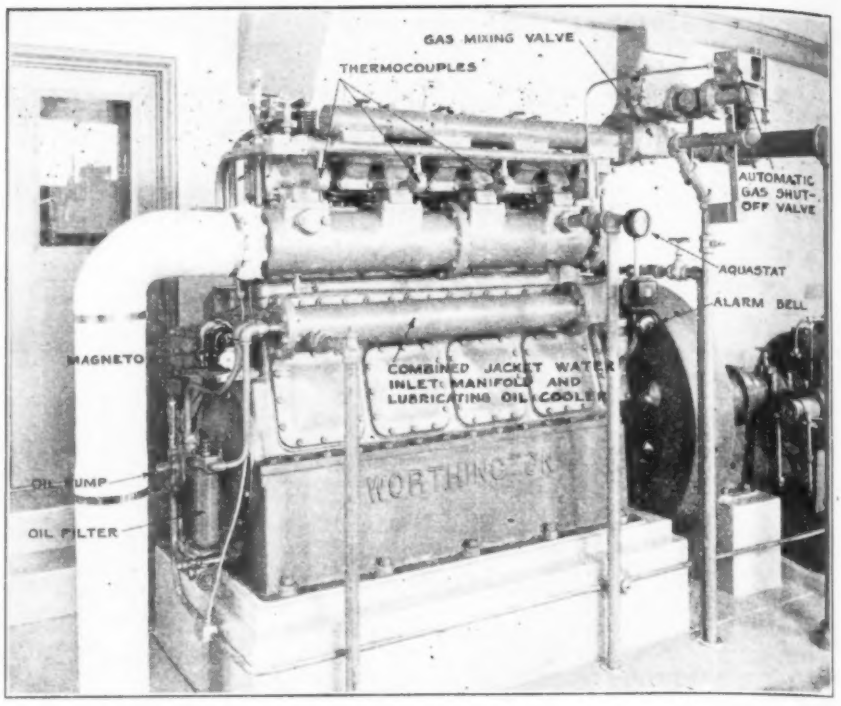
Average	40 KWH
Moderate Peak	99 KWH
Extreme Peak	124 KWH

A generating plant to take care of the above loadings will be as follows:

One 60 KW generator set to provide power for average demands, with sufficient reserve power for minor fluctuations.

One 60 KW generator set to serve as alternate to the first set, and to provide the additional power required for the peak demands.

Note:—Both generators operating in parallel will generate 120 KWH, and will easily stand the temporary overloading required to produce 125 KWH.



Worthington 120 H.P. Engine at Ann Arbor, Mich. Direct Connected to Blower

Some form of standby power service is always desirable. If the charges are within reason, an outside power company connection is the most practical. If such charges are too high, and they usually are, an arrangement may be made to use the local gas company's gas in case the supply of sewage gas fails. The scheme has proved entirely feasible and economical at existing plants.

If gasoline is to be used, a carburetor should be provided on the engine by means of which the engine may be operated as a gasoline engine. In the case of the Rahway Valley Plant, it is intended to cut off the local power company entirely and to use gasoline as the auxiliary fuel to serve as a standby.

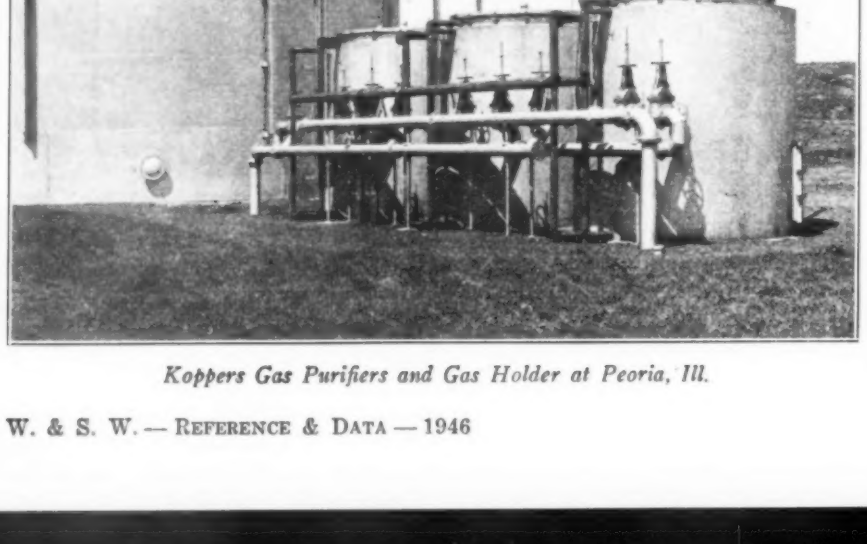
Selection of the Engine

The More Important Considerations

Many gas engines are on the market, some of which have been especially adapted to the use of digester gas as a fuel. The most serviceable type is the heavy-duty, slow-speed engine. Such engines are built to run continuously for a number of years with low cost of repairs and maintenance, and embody the standards of construction and the principal features of the heavy-duty Diesel engine.

Some sewage treatment plants have installed the lighter-weight, higher-speed automotive type of gas engine which is less expensive in first cost. However, experience has proven that in general these engines cannot be subjected to continuous service over protracted periods of time without high maintenance costs. In addition, their total useful life is much shorter than that of the heavy-duty engine, so that in the long run, the heavy-duty engine may be expected to prove the more economical type.

The special features to be considered in choice of engines are those involving long life and low maintenance costs. Valve-in-head engines are preferable in the smaller sizes. In the larger sizes, valves should be in removable cages, or should be otherwise easily removable for convenience in inspection and grinding of valves. Renewable valve-seat inserts should be provided for the exhaust valves, preferably of some high grade heat resisting metal such as "Stellite."



Koppers Gas Purifiers and Gas Holder at Peoria, Ill.

An engine of unit-block frame type, bolted direct to the engine base, is preferred. Each cylinder head should be a separate casting, and renewable cylinder liners of a high strength material should be provided so that wear in a cylinder will require the replacement of a liner only, rather than a complete cylinder. It was found at the Coney Island (N. Y.) Plant that the liners can stand three reborings before replacement is necessary.

The main bearings should be lined with a high-grade anti-friction metal, and should be fitted so that they can be removed without disturbing the crankshaft. Easy access should also be provided to the connecting-rod bearings. Water jacket space should be accessible for cleaning through ample covered openings inside of the frame.

When the engine is direct-connected to a generator, a fly wheel should be mounted on the drive end of the crank shaft. It should be dynamically balanced and have sufficient inertia to insure the degree of uniform rotation required for generator operation. A governor should be provided which will satis-

factorily control the speed of the engine to the limits required for the guaranteed operation of the generator.

The customary oil filter and air filter should also form a part of the installation. Safety devices are also very desirable, such as an electric alarm and automatic shutdown system, to protect the engine against low lubricating oil pressure and excessive jacket water temperature.

The desirable features *not* customarily found on automotive types of engines may be summarized as follows:

1. Unit-block frame bolted direct to engine base.
2. Cylinder heads as separate castings.
3. Renewable cylinder liners.
4. Renewable valve-seat inserts for exhaust valves.
5. Valves readily removable.
6. Main bearings mounted in engine base.
7. Main bearings readily removable.
8. Water jacket space accessible for cleaning.
9. Flywheel, if engine drives a generator.
10. Governor to control engine speed.
11. Safety devices.
12. Piston speed not to exceed 1000 feet per minutes.
13. Brake mean effective pressure not to exceed 70 pounds per square inch.

Quantity, Quality and Dependability of Sludge Gas

The evolution and production of sewage gas is normally a continuous and uninterrupted process, resulting from the biological decomposition of sewage sludge in digestion tanks. During this process a portion of the volatile organic matter in the sludge is converted into a combustible gaseous mixture which is approximately

Methane	64%
Carbon Dioxide	30%
Nitrogen	5%
Hydrogen Sulphide	Trace
Other Gases	1%

Weekly analyses of the gas at Rahway have been run since the plant was placed under operation. From these analyses (made with a Bureau of Mines Gas Analysis Apparatus) the average heat value of the gas has been found to be about 650 Btu. per cubic foot. This is slightly higher than commercial gas, which runs about 550 Btu. per cubic foot. In an internal combustion engine, about 10% of this heat is not available, this being the heat of vaporization. Thus the dependable minimum heat value of the gas becomes 575 to 600 Btu. per cubic foot.

Importance of Gas Storage

Table 2 indicates that a uniform and dependable supply of gas is available at our plant at all times. The average daily gas production for January to October was 71,000 cubic feet. However, since individual days have shown productions as low as 60,000 cubic feet, it has been assumed for the purpose of this study that at all times 60,000 cubic feet of gas will be available as the dependable minimum per 24 hours for power generation purposes. The assumption is doubly conservative due to the fact that we have a reserve gas supply of approximately 45,000 cubic feet in storage under 6 inches water pressure. This reserve supply is held in our secondary digestion tanks, the upper portion of which are in reality single-lift gas holders. It becomes apparent that one of the prime requisites of a practical and successful sewage-gas engine installation is a gas holder having ample storage capacity to carry over during periods of lower-than-average gas production.

Hydrogen Sulphide and Its Removal

The presence of hydrogen sulphide (H_2S) in objectionable quantities in digester gas may prove injurious to the pistons and cylinder walls of gas engines. While hydrogen sulphide itself is not seriously corrosive, its products of combustion, water and sulphur dioxide (SO_2) unite to form the highly corrosive sulphurous acid (H_2SO_3). The same products of combustion result from the presence in the gas of any form of sulphur; therefore, any volatile sulphide is just as objectionable in an engine fuel as is hydrogen sulphide.

Where the sulphide content of a sewage gas exceeds 0.07 percent by volume, or approximately 50 grains per 100 cubic feet, scrubbers should be used to clean the gas before it enters the engine. Sulphur as hydrogen sulphide may be removed by passing the gas through a bed of finely divided iron oxide and wood shavings. The iron oxide reacts with the hydrogen sulphide to form sulphide of iron and water, according to the following equation.

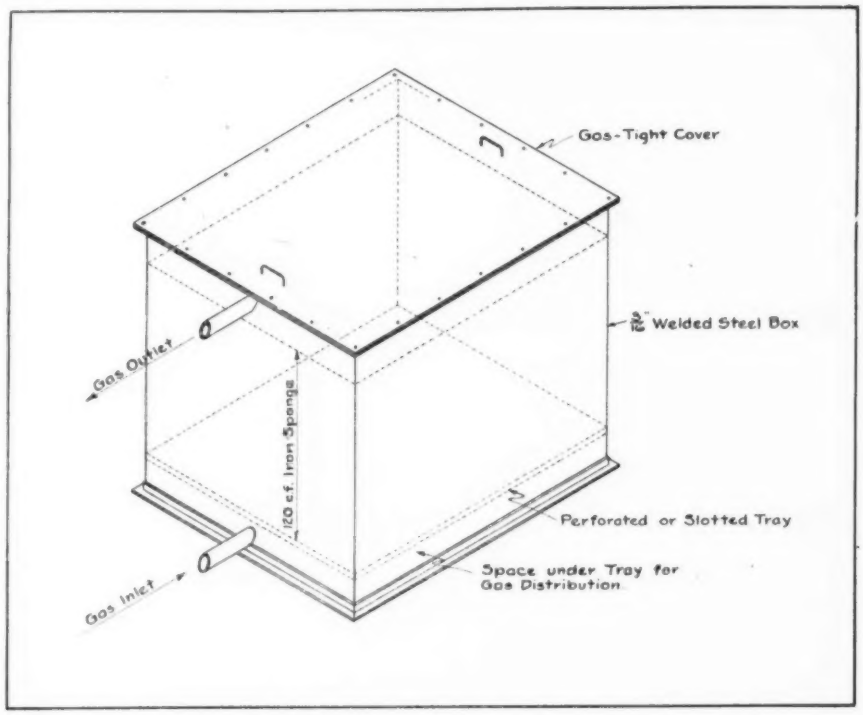
$$Fe_2O_3 + 3H_2S \simeq Fe_2S_3 + 3H_2O$$

The wood shavings merely serve to keep the mass of iron oxide open, forming an "iron sponge," so that the gas can pass through without too much resistance.

At most sewage treatment plants, little or no trouble has been experienced due to hydrogen sulphide in the gas. Some plants, however, have found it necessary to first remove the sulphur. Several of these have installed a commercial type of scrubber, among them the plants at Peoria, Illinois, Fort Atkinson, Wisconsin, and Battle Creek, Michigan.

An inexpensive, home-made gas scrubber can be constructed by following the design used at Galesburg, Illinois (3), as here sketched. It consists of a rectangular box providing a convenient depth of "iron-sponge" and a perforated or slotted tray which carries the sponge. The tray is supported about three inches above the bottom of the box to permit the gas to be distributed over the entire area before passing upward through the sponge.

Since the chemical action between hydrogen sulphide and the iron oxide takes place more readily at temperatures above 60° F., the box should either be located in a warm place, or insulated,



Home-Built Sulphide Scrubber at Galesburg, Ill.

or provided with heating coils. (The Peoria scrubbers here pictured are provided with artificial heat.) The inside of the box should be well coated with an asphaltic paint to prevent corrosion.

The calculations for a gas scrubber for 80,000 c.f.d. of gas containing 100 grains H_2S per 100 cubic feet are as follows:

1. Sufficient "iron sponge" should be provided to last about 60 days.
2. 1 cu. ft. of sponge contains about 20 lbs. of ferric iron.
3. 20 lbs. of ferric iron will theoretically react with 127,000 grains of H_2S.
4. Practical considerations cut this figure to about one-third, or 40,000 grains of H_2S.
5. Average H_2S content in the gas under question is 100 grains per 100 cu. ft.
6. Total H_2S in 60 days = 100 x 800 x 60 = 4,800,000 grains.

7. Total quantity of "iron sponge" required is

$$\frac{4{,}800{,}000}{40{,}000} = 120 \text{ cu. ft.}$$

The useful life of the sponge may be extended by regeneration. If the exhausted (sulphided) sponge is *carefully* exposed to the air, the iron sulphide will absorb oxygen, enabling the iron to revert back to its original ferric oxide condition as follows:—

$$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$$

This reaction generates so much heat that the sponge may take fire and be ruined. However, rate of regeneration may be controlled by wetting the old sponge thoroughly with water, and then removing it from the box to a pile in the open air. When it has changed from a black to a dark brown color, it is again ready for use. "Iron Sponge," thus regenerated, may be used two to three times before finally discarding.

When charging the box with sponge, care must be taken to pack uniformly. It should be lightly tamped several times while filling. Careful tamping around the sides of the box will prevent leakage of gas.

An accompanying picture shows three home-built scrubbers at hicago Heights, Ill.

Three Home-Built Gas Scrubbers at Chicago Heights, Ill.
Beyond is 125 H.P. Climax engine direct connected to 2500-cu. ft. Pottstown blower.

Engine Gas Supply

Most engine manufacturers will guarantee the fuel consumption at full load to be not in excess of 10,000 Btu. per BHPH. This is equivalent to 15,000 Btu. per KWH. For a sewage gas having a low heat value of 575 Btu. per cubic foot, the consumption will be

$$\frac{15{,}000}{575} = 26.1 \text{ cu. ft./KWH}$$

At other loadings, the fuel requirements will be approximately as follows:—

1/2 Load—32.7 cu. ft./KWH
2/3 Load—29.3 cu. ft./KWH
5/6 Load—27.5 cu. ft./KWH

The total daily engine gas consumption shown in Table 3 was computed on the basis of using one engine up to 60 KW demand, and above 60 KW demand using both engines in parallel, each taking one-half the total load.

The sewage gas is introduced into the engine through a gas mixing-valve which mixes the gas with atmospheric air in the proper proportions. The function of this valve is similar to that of a carburetor on a gasoline engine. It should contain an air valve and a gas valve, each separately regulated in order that the fuel mixture may be changed to suit the varying Btu. content of the sewage gas.

The gas pressure ahead of the mixing valve should be reduced by means of a suitable pressure regulator to atmospheric pressure. To insure a constant supply of gas at atmospheric pressure at all times, a gas reservoir is usually installed between the mixing valve and the pressure regulator. The size of this reservoir depends upon the engine rating, but should not be less than about 30 cubic inches per horsepower.

Heat Recovery

(a) From Jacket Water

In most cases where sewage gas is being used for power, part or all of the waste heat from the engine is recovered for the heating of digestion tanks and buildings. If this were not done, the heat normally derived from the gas would have to be replaced by other fuels, such as coal or oil. Such an arrangement would probably prove economically unsound. Therefore, if gas is used for power purposes, no additional heating cost should be incurred, and such heat as may be required should be obtained from the engine waste heat, and from the excess gas.

The heat consumed in a gas engine, the heat wasted, and the heat which is recoverable depend upon the type of engine. For a 90 HP., four-cycle, slow-speed engine operating under full load, a typical heat balance is as follows:—

Heat going to useful work	25.5%
Heat to radiation	3.5%
Heat to jacket cooling water	35.5%
Heat to exhaust and friction	37.5%

Of the above heat, all of that carried away by the jacket cooling water can be recovered by connecting the jacket water piping into the hot water heating system. For best operating conditions, the cooling water should enter the engine at between 110° F. to 130° F., and should leave the engine at between 140° F. to 160° F. Approximately 3300 Btu./-BHPH must be removed from the engine jacket water to insure efficient cooling. Therefore, if the engine jacket water is passed through the digestion tank heating coils, these coils, acting as a water cooler, must be able to extract this amount of heat from the jacket water both winter and summer. If not, all or part of the jacket water must be circulated through a separate water cooler.

For a 90 HP engine operating at full load the heat recoverable from the jacket water is therefore

$$3300 \times 90 = 297{,}000 \text{ Btu/hr.}$$

The amount of a jacket cooling water required for a 30° F. temperature rise will be

$$Q = \frac{3300 \times 90}{30\ (^\circ \text{ Temp. diff.}) \times 8.34} = 1190 \text{ gph.}$$

In the jacket water system, therefore, we must provide a cooler (digestion tank or other) to extract the necessary heat from the water. We have calculated that a circulating water pump of at least 20 gpm (1190 gph) capacity will be required to ensure positive water circulation. A vented surge tank should be installed at the high point of the jacket water system, either between the engine outlet and the cooler, or just ahead of the circulating pump. Thermometers should be provided at the cold water inlet and the hot water outlet.

(b) From Exhaust Gas

A portion of the heat normally carried away by the exhaust gases is recoverable. The quantity recovered is governed by practical limitations in the size of the waste heat boiler, and also by the lower temperature limit to which gases can be safely cooled without condensation and the consequent corrosion of the surfaces with which they come in contact.

The importance of avoiding condensation of the moisture contained in the exhaust gases cannot be too highly stressed. The point of condensation, often called the dew point, has been found to be about 130° F. However, an exhaust gas temperature slightly higher than 130° F. is not sufficient to avoid condensation, due to the fact that exhaust gas temperatures drop very sharply when

they come in contact with surfaces having a water temperature below 130° F.

This sudden temperature drop is due to the inability of the gas film adjacent to the heating surface to transmit the heat from the main body of the gases to the water quickly enough. The resistance offered by the gas film causes the moisture in the gases to condense on the cold surfaces even though the main body of gases are at temperatures far above the dew point. Hence it is obvious that the water inlet temperature should not be less than 130° F., and the lower temperature limit of the main body of the exhaust gas should be well above the dew point. Experience has indicated that 300° F. is a safe minimum exhaust gas temperature.

Where 130° F. water is not available, the ideal method of reclaiming waste heat is by means of a waste heat boiler generating low pressure steam. The steam generated therein is delivered to an independent tubular heater through which water passes in the tubes. When the steam condenses in the independent heater, the condensate returns by gravity to the waste heat boiler where it is again evaporated. In this manner the cycle is closed and the water temperature remains well above 130° F., except for short periods when starting up after long shut downs. Nevertheless, practically all condensation with its consequent corrosion is eliminated.

At Rahway we have decided upon a waste heat boiler which will extract sufficient heat to cool the gas from 900° F. to 300° F. at full load. Obviously, at fractional loads, the final gas temperature will be under 300° F. due to the lower initial temperature and smaller gas quantities, but at low loads it will still be above the dew point. As a further precaution against corrosion, the cooling water will first be circulated through the engine jackets as the cooling medium for the engines. In so doing, the water will be preheated from 110° F. to 140° F. before entering the waste heat boiler. This double precaution against the possibility of a highly corrosive condensate appears to be the best guarantee for the long life of the equipment, and for low maintenance costs.

A waste heat boiler (see first cut) is a shel land tube type of boiler, the exhaust gases being passed through the boiler tubes, and the heat being absorbed by the cooling water which completely fills the shell and surrounds the tubes. The exhaust gases, cooled down considerably by the boiler, pass on out to atmosphere. The waste heat boiler itself will also serve as a silencer, no further silencing being necessary. Where a by-pass around the boiler is provided, a suitable silencer should be installed on the by-pass line. The arrangement proposed at Rahway will make it possible to by-pass all or a part of the exhaust gases around the boiler by means of a 3-way regulating valve. The piping is also so arranged that the jacket water can be by-passed around the waste heat boiler.

A pyrometer will be provided with a sufficient number of themocouple selection points to permit temperature readings of the exhaust gas to be taken at each cylinder, and at the discharge from the waste heat boiler.

Naturally, the amount of heat going into the exhaust gas depends upon the bore and stroke, number of cylinders, speed and type of engine. A four-cycle engine with water-cooled exhaust manifold will produce exhaust gases having temperatures of from 800° F. to 900° F., while the exhaust gases from a two-cycle engine will probably range from 300° F. to 500° F.

A typical range of exhaust gas quantities and the corresponding temperatures for a 90 H.P., four-cycle engine operating under several loadings is shown below. This data must be obtained from the manufacturer of the engine to be used.

	Exhaust Gas Quantity	Temperature
1/2 Load	683 Lbs./hr.	850
2/3 Load	845 Lbs./hr.	866
3/4 Load	918 Lbs./hr.	875
5/6 Load	994 Lbs./hr.	883
Full Load	1130 Lbs./hr.	900

Obviously, the quantity of heat which may be extracted from the exhaust gas depends upon the difference between the initial and final temperatures, and the specific heat of the gas. The specific heat of the exhaust gas from a gas engine will be about 0.24, this representing the ratio of the heat required to raise one pound of the gas 1° F., to the heat required to raise one pound of water 1° F. Therefore, the heat recoverable from the exhaust gas of a 90 HP., four-cycle engine operating under full load will be

$$1130 \text{ lbs./hr.} \times (900° - 300°) \times 0.24 = 162.720 \text{ btu/hr.}$$

(c) From Engine Radiation

The heat radiated from the engines (about 3.5%) cannot be transferred to the hot water heating system, but it does assist in the heating problem by partially heating the engine-room, thus relieving the heating system of this portion of the total heating load. Generally speaking, the radiation losses at the engine will be from 2 percent to 4 percent of the total heat input.

Heat from Excess Gas

At Rahway we have at present a hot water heating plant which heats the digestion tanks and all buildings. The boilers are operated exclusively on sewage gas. The Heat Exchange Diagram on the next page shows how the heated water from the engine-room will be run directly into the return line at the bottom of the boilers, and circulated through the boilers where the temperature will be raised to the desired degree. The return water to the engines will be taken from the digestion tank return water, which averages about 110° F. In using the boilers to "jack-up" the temperature of the heating water, we must rely on the sewage gas which may be left over after all engine requirements have been satisfied. Since the boiler efficiency approximates 68 percent, the boiler heat output which is available when one engine is operating under a 60 KW demand will be

$$\frac{22{,}500 \times 650 \times 0.68}{24} = 415{,}000 \text{ btu/hr}$$

This is shown in Table 3.

Thus it is apparent that the system will be extremely simple and yet highly flexible. The combined heat from the exhaust gases and the jacket cooling water can be used to heat the digestion tanks in summer, and to aid in the heating of tanks and buildings in the winter. Exhaust gas heat can be recovered, or it can be by-passed as desired. Since our average power load is 40 KW, it can be seen that sufficient heat is available to meet all normal winter heating requirements

Construction and Operating Costs

Estimate of Cost

Two 90 HP.—60KW—100 KVA heavy duty gas-engine generator sets complete with gauge boards, gas reservoirs, Maxim silencers, exhaust gas pyrometers, electric alarm and shutdown systems, water circulating pumps, starting air equipment, gasoline carburetors, and installation	$19,000.00
Two Waste Heat Boilers	660.00
Two 3-Way Regulating Valves	240.00
Generator panels, with ammeters, voltmeters, wattmeters, frequency meters, voltage regulators, field rheostats, Synchroscope	2,340.00
Distribution Panel, Electric Wiring and Lighting	1,600.00
Station Piping	1,000.00
Outside Piping	3.500.00
Building (29' x 39' x 15')	6,000.00
1½ Ton Crane and Hoist	450.00
Engine Foundation (3 Engines)	800.00
Gas Meter	400.00
Contingencies	1,200.00
Total Estimated Construction Cost	$37,190.00
Legal, Administrative, etc.	3,000.00
Total Estimated Cost	$40,190.00

Amortization and Operating Costs

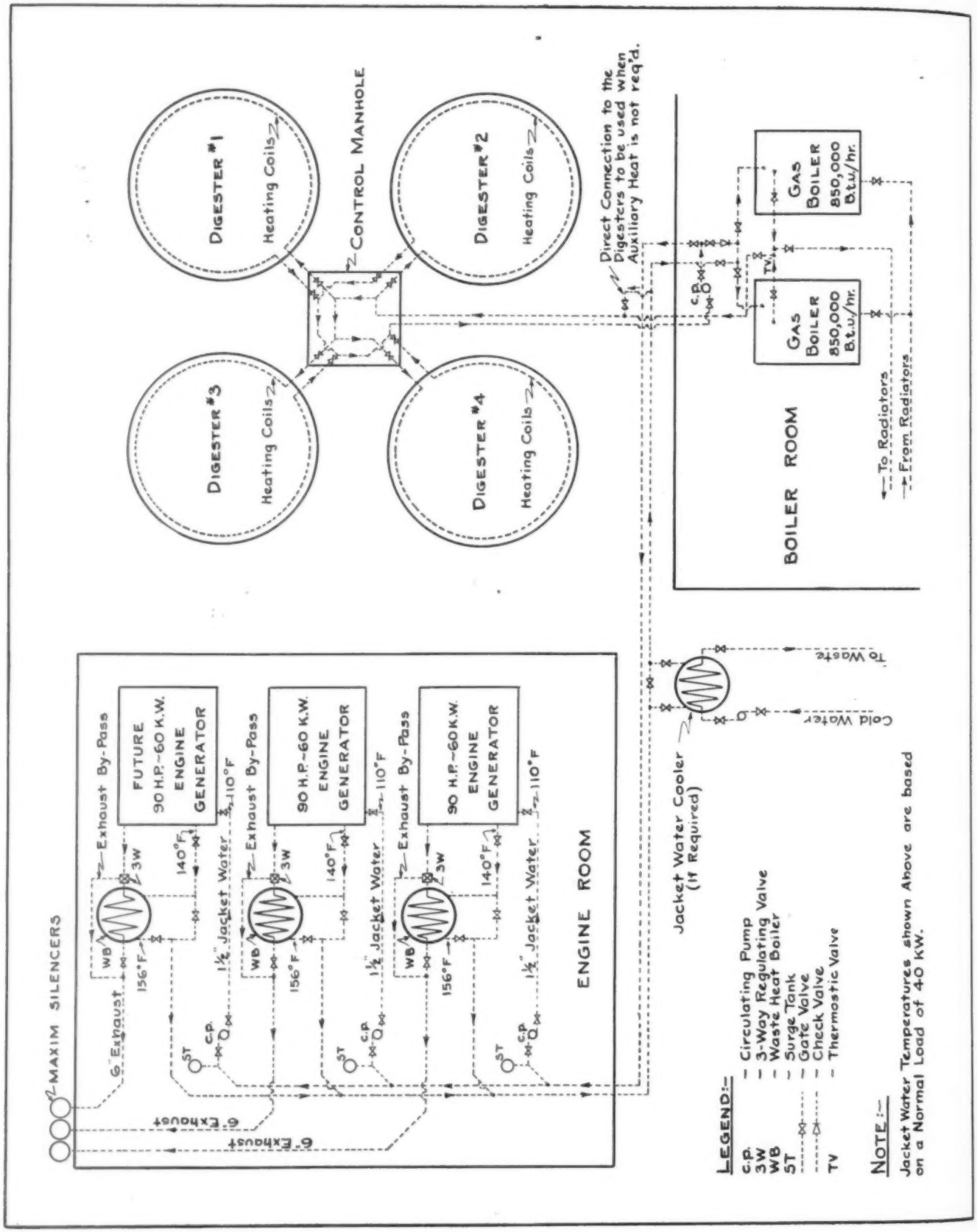
Gas engines, when on continuous service, are generally conceded to have a useful life of from 15 to 20 years. With two engines, each capable of carrying the normal load, the service is divided. Hence, the life of each engine may be conservatively set at 20 years.

By looking back at Table 1, it will be seen that in most cases the cost of additional labor to operate and maintain the engines is negligible. In fact, a number of the replies indicated that no additional labor cost was incurred.

Experience on the cost of repairs and lubricating oil seems to differ widely. A fair allowance for repairs is $2.00 per BHP per annum. This figure is somewhat higher than the engine manu-

facturers themselves predict on the basis of their own experience, and is thus felt to be sufficiently conservative for the purpose of this analysis.

Lubricating oil at most plants amounts to about 1 gallon for 2000 BHPH. However, oil consumption can be reduced somewhat by the use of oil refiners. At the Rahway plant, we estimate a total of 335,000 KWH per annum, which is equivalent to 500,000 BHPH. Our oil consumption, therefore, is expected to be approximately 250 gal.



Annual Charges and Savings

Interest on Investment @ 4%	$1,607.60
Amortization of Engine— $\frac{1}{20}$ x $21,300	1,065.00
Amortization of Miscellaneous Equipment— $\frac{1}{25}$ x $6,400	256.00
Amortization of Permanent Structures and Piping— $\frac{1}{30}$ x $12,490	416.33
Repairs—57 BHPH/annum @ $2.00	114.00
Lubricating Oil—250 gallons @ 12c	30.00
Estimated Annual Cost	$3,488.93
Present Annual Power Cost*	5,700.00
Net Annual Saving (based on present power cost)	$2,211.07

*Our purchased power cost will increase from year to year as the sewage load increases, hence the savings will likewise increase.

References

(1) W. B. Walraven "Development of Power from Sewage Sludge Gas," Sewage Works Journal, Vol. 4, Page 614 (July, 1932). "Experience with Gas Engine Operation—During Three and One-Half Years of Use." Water Works & Sewerage, p. 370, Vol. 83 (October, 1936). Water Works & Sewerage, p. 151, Vol. 80 (May, 1933).

(2) W. A. Sperry "Gas Engine Installation—Aurora, Illinois," Water Works & Sewerage, Page 11, Vol. 84 (January, 1937) and Page 327, Vol. 84 (September, 1937).

(3) L. W. Hunt, Chief Chemist, the Galesburg Sanitary District—by letter.

TABLE 1. TABULATION OF DATA ON POWER GENERATION FROM SEWAGE GAS

(Taken from replies to questionnaire)

Location	Pop. Served	Total H.P.	Make of Engine	Gas Production c.f.d.	Gas Consumption cu. ft.	Net Annual Savings	Annual Repairs	Annual Lubric. Oil	Additional Annual Labor Cost
Battle Creek, Mich.	36,300	60	Le Roi	59,000	8/BHPH	$2,004	$ 55	$ 90	None
Los Angeles, Cal.	374,000	450	Clark	250,000	24/BHPH	4,600	100	325	None
Green Bay, Wisc.	40,000	210	Worthington	40,000	26/KWH	2,835	96	189	$234
Cedar Rapids, Iowa	55,000	200	Worthington	147,760	15/BHPH	6,000	300	700	275
Janesville, Wisc.	20,000	30	Worthington	25,000	17/BHPH	850	600	110	150
Grand Rapids, Mich.	178,000	150	Buda	138,000	——	1,000	15	30	30
Fort Atkinson, Wisc.	6,000	15KVA	Le Roi	75,000	24/Kwh	1,950	300	75	None
Richmond, Ind.	28,000	120	Worthington	25,000	9.5/BHPH	6,000	None	200	None
Ann Arbor, Mich.	40,000	120	Worthington	50,000	15/BHPH	6,000	None	170	None
Topeka, Kans.	50,000	360	Worthington	Ample	——	5,400	200	425	——
Aurora, Ill.	49,000	140	Climax	49,500	21.8/BHPH	*	219	88	None
Kokomo, Ind.	36,000	45	Worthington	15,000	19/BHPH	1,800	None	55	None
Toledo, Ohio	60,000	535	Rathbun	250,000	9500 Btu/ BHPH	13,299	382	576	None

*Plant operating cost reduced 20%.

TABLE 2. GENERAL DATA ON POWER, GAS PRODUCTION, AND HEAT REQUIREMENTS

(As determined for the Rahway Valley Plant)

Month	Hourly Rates of Power Consumption			Max. Demand from Demand Chart	Gas Production		Heat Requirements				
							Digestion Tanks				
	Max. Day KWH	Min. Day KWH	Monthly Aver. KWH	KW	Average c.f.d.	Maximum c.f.d.	Aver. Circ. Water g.p.h.	Temp. Diff. °F	Heat Req'd Btu/hr.	Heating of Buildings	Total Heat Required Btu/hr.
January	80	23	35	99	63,000	85,000	3,600	18	540,000	400,000	940,000
February	57	30	39	70	68,000	86,000	3,500	17	485,000	400,000	885,000
March	73	33	42	78	67,000	86,000	3,620	21	635,000	350,000	985,000
April	60	30	39	76	72,000	89,000	3,500	23	670,000	200,000	870,000
May	37	27	31	50	61,000	79,000	3,250	19	516,000	75,000	591,000
June	60	23	32	51	73,000	87,000	2,780	23	535,000	0	535,000
July	113*	27	43	119*	72,000	85,000	3,480	13	377,000	0	377,000
August	40	27	35	72	70,000	81,000	3,400	16	453,000	0	453,000
September	114*	27	39	124*	85,000	104,000	3,100	15	387,000	0	387,000
October	40	27	37	60	78,000	103,000	3,250	17	462,000	80,000	542,000
Average					71,000						

*Exceptionally Heavy Storms.

TABLE 3. FUEL AND HEAT BALANCE

Daily Load	Engine Gas Consumption		Excess Gas*	Boiler Heat Available from Excess Gas**	Recoverable Heat		Radiation from Engines		Total Heat Available	Aver. Heat Req'd during Winter Months	Max. Heat Req'd for a Zero Day
KWH	Btu/KWH	c.f.d.	c.f.d.	Btu/hr.	From Jacket Water Btu/hr.	From Engine Exhaust Btu/hr.	% Loss	Heat Btu/hr.	Btu/hr.	Btu/hr.	Btu/hr.
80	16,800	56,000	4,000	74,000	396,000	238,000	2¼	30,000	738,000	850,000	1,070,000
70	17,600	51,200	8,800	162,000	345,000	216,000	2½	34,000	757,000	850,000	1,070,000
60	15,000	37,500	22,500	415,000	297,000	163,000	1½	15,000	890,000	850,000	1,070,000
50	15,800	33,000	27,000	495,000	248,000	138,000	2	17,000	898,000	850,000	1,070,000
40	16,800	28,000	32,000	590,000	197,000	119,000	2¼	16,000	922,000	850,000	1,070,000
30	18,800	24,000	36,000	660,000	149,000	95,000	2½	16,000	920,000	850,000	1,070,000

*Daily Average Gas Production to be expected is 60,000 c.f.d.
**Hot Water Boiler Efficiency estimated at 68%.

NOTES:
High heat value of sewage-gas = 650 Btu; low heat value = 575 Btu.

Fuel requirements and heat recovery, based on the following:
Engine—Worthington 90 H.P.—60 K.W. Type BG-3.
Waste Heat Boiler—Davis Paracoil N-70.

OPEN CHANNEL FLOW

Solved by Nomograph Based on Manning's Formula

By DONALD R. KEITH
Civil Engineer, Division of Water, Columbus, Ohio

BEFORE entering into an explanation of the use and operation of Manning's Formula, a brief introduction should be made as to why it was used for the basis of this chart.

Kutter's Formula is generally preferred for its accuracy and a great number of engineers have become accustomed to estimating the condition of a stream in terms of Kutter's "n". Unfortunately, Kutter's Formula does not lend itself easily to a nomographic type of chart without complicating the whole process. Manning's Formula was therefore carefully studied in comparison. Kutter and Manning Formulas use the same value for "n" and, when r = 1 meter, they are identical expressions and give identical results.

Several typical problems were solved by each formula and the results compared. These all checked to the first and second decimal places and, in a few instances, to the third decimal place. In no instance did the third place differ more than one point at most.

Furthermore, Manning's Formula, $V = \frac{1.486}{n} r^{2/3} s^{1/2}$, adapts itself very nicely to nomographic chart calculation.

How to Use the Chart

An explanation of the use and operation of the accompanying chart follows:

A glance at the chart will show that all scales, with the exception of the n-scale, read up. The n-scale reads down. The product of $r^{2/3} \times s^{1/2} \times$ the constant 1.486 is divided by "n"; therefore, the n-scale must be inverted.

The s-scale represents the slope or hydraulic gradient in decimals of a foot per lineal foot.

The r-scale represents the hydraulic radius, which is equal to A/p, in which A = the area of the cross-section and p = the length of the wetted perimeter of the cross-section, in feet.

The v-scale represents the velocity of flow in feet per second.

The Q-scale represents the discharge in cubic feet per second on its right side, and gallons per minute on its left side. The Q-scale is calculated from Q = Av.

The A-scale represents cross-sectional areas from 10 sq. ft. to 10,000 sq. ft.

Example (1)

In the solution of the first problem, as shown by one group of index lines on the chart, we have given:

s = 0.00015 ft. per lineal foot
r = 2.19, and n = 0.035
Required, the velocity "v"

First, align the straight-edge from s = 0.00015 to r = 2.19; from the intersection of this line with the axis, align the straight-edge to n = 0.035; where the straight-edge cuts the v-scale, read v = 0.877, the answer.

In this problem, suppose the cross-sectional area A = 100 sq. ft. and the discharge Q is desired. Set the straight-edge at the point just found above, namely, v = 0.877, and align it to A = 100; where the straight-edge cuts the Q-scale, read Q = 87.7 cfs. or Q = 39,359.76 gpm. (gallons per minute). This scale cannot read that close, but it does show between 39,000 and 40,000 gallons per minute.

Example (2)

In the solution of the second problem shown by another group of index lines on the chart, s = 0.0001, r = 1.0, and n = 0.01 (incidentally, this problem was used to spot the starting points when laying out the scales).

First, align the straight-edge from s = 0.0001 to r = 1.0; from the point where the straight-edge cuts the axis, align to n = 0.01; where the straight-edge cuts the v-scale, read v = 1.486 ft. per sec.

Suppose in this case the cross-sectional area A = 1,000 sq. ft. and it is desired to know the discharge Q. Set the straight-edge to 1.486 on the v-scale (the velocity just found), then align to A = 1,000; where it cuts the Q-scale, read Q = 1,486.0 cfs. or Q = 667,000 gpm.

The index lines plotted on the chart merely trace the operations in solving the problems just explained. They are not there for any other purpose.

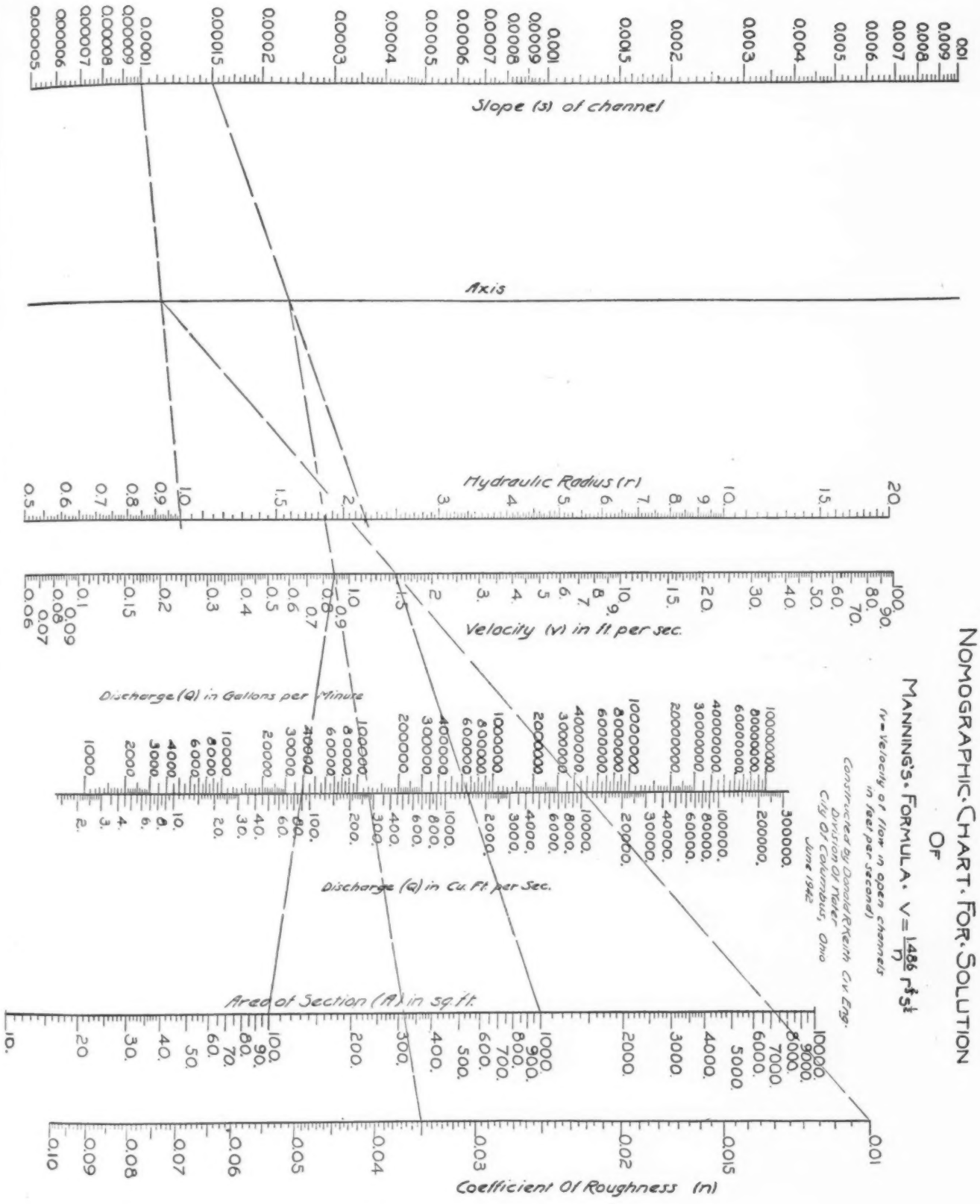
Values for "n"

Values for "n" vary from 0.01 for neat cement, 0.013 for clean brick, 0.015 for unclean brick or cement, 0.02 for new canals, 0.025 for average canals, 0.035 for moderately rough earth and rock channels, 0.05 for channels in very poor condition, and 0.07, or even 0.08, for channels with bank-slopes and bottoms obstructed with small trees and undergrowth.

CARRYING CAPACITY OF SEWER PIPE—GALLONS PER MINUTE

(Based on "Hydraulic Tables" by Williams & Hazen)

Size, Inches	1" Fall in 100 Feet	2" Fall in 100 Feet	3" Fall in 100 Feet	6" Fall in 100 Feet	9" Fall in 100 Feet	12" Fall in 100 Feet	24" Fall in 100 Feet	36" Fall in 100 Feet
4	....	.....	.....	.....	86	102	149	186
6	....	.....	.....	204	256	297	269	534
8	....	.....	.....	437	539	632	921	1143
9	....	.....	.....	601	749	876	1272	1580
10	....	.....	537	781	974	1138	1653	2055
12	....	730	869	1264	1571	1835	2695	3345
15	....	1242	1556	2275	2835	3300	4790	5950
18	....	2030	2510	3670	4580	5340	7760	9665
24	2985	4325	5390	7810	9740	11380	16530	20550
27	4040	5875	7325	10690	13270	15520	22530	27850
30	5340	7760	8670	14080	17500	20450	29750	37150
36	8740	12600	15640	22700	28350	33000	47900	59500


Slope (S) of channel
Axis
Hydraulic Radius (r)
Velocity (v) in ft per sec.
Discharge (Q) in Gallons per Minute
Discharge (Q) in Cu Ft per Sec.
Area of Section (A) in Sq. ft.
Coefficient Of Roughness (n)

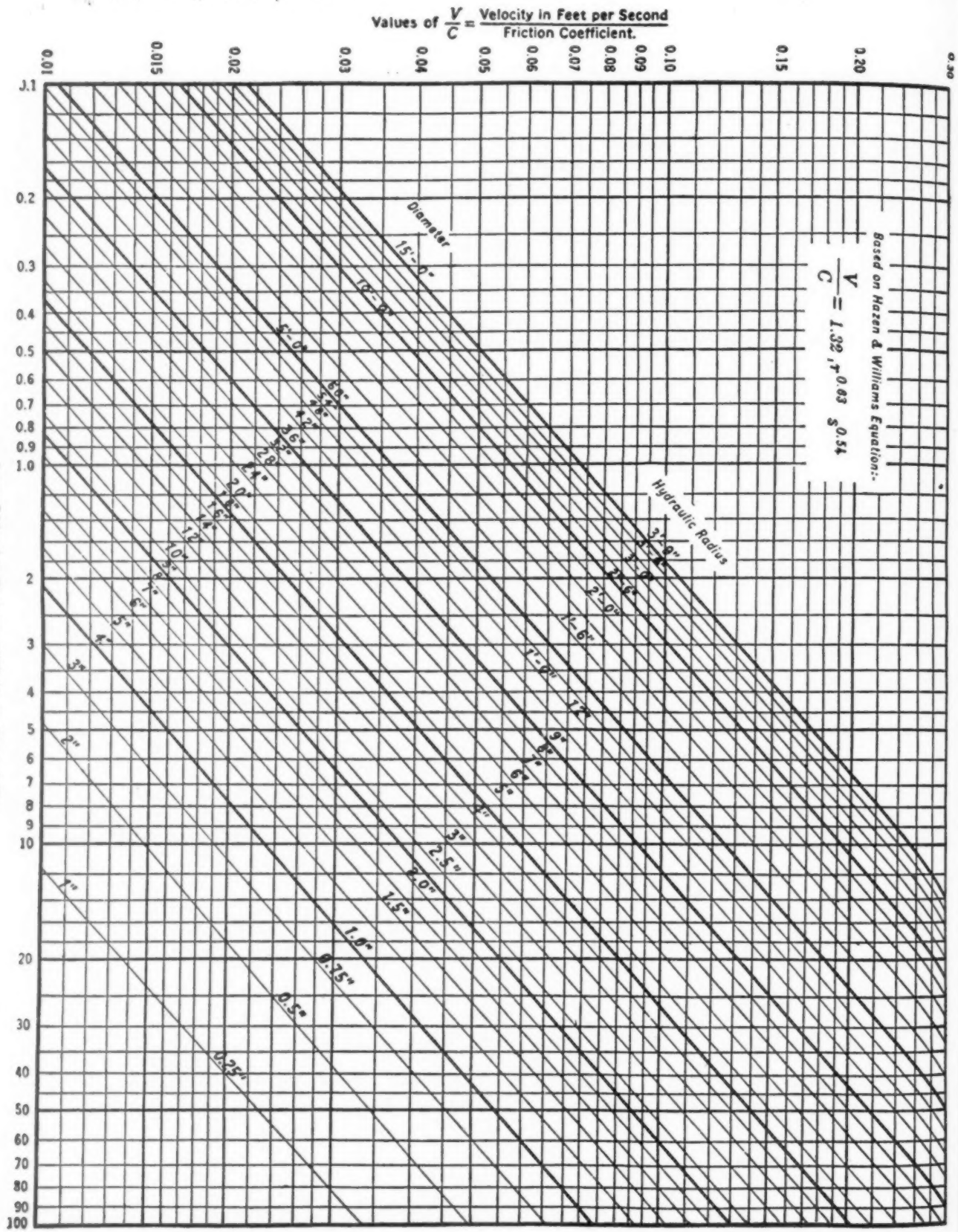
Nomographic Chart For Solution Of Manning's Formula $V = \frac{1.486}{n} r^{\frac{2}{3}} S^{\frac{1}{2}}$

(v = Velocity of flow in open channels in feet per second)

Constructed by Donald R. Keith, Civ. Engr.
Division Of Water
City Of Columbus, Ohio
June 1942

Index shows that when S = 0.0001, r = 1.0, and n = 0.01, V = 1.486; A = 1000, and Q = 1486.0
Also, when S = 0.00015, r = 2.19, and n = 0.035 V = 0.877; A = 100, and Q = 87.7

CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE



From "Hydro-Electric Handbook"—John Wiley & Sons

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

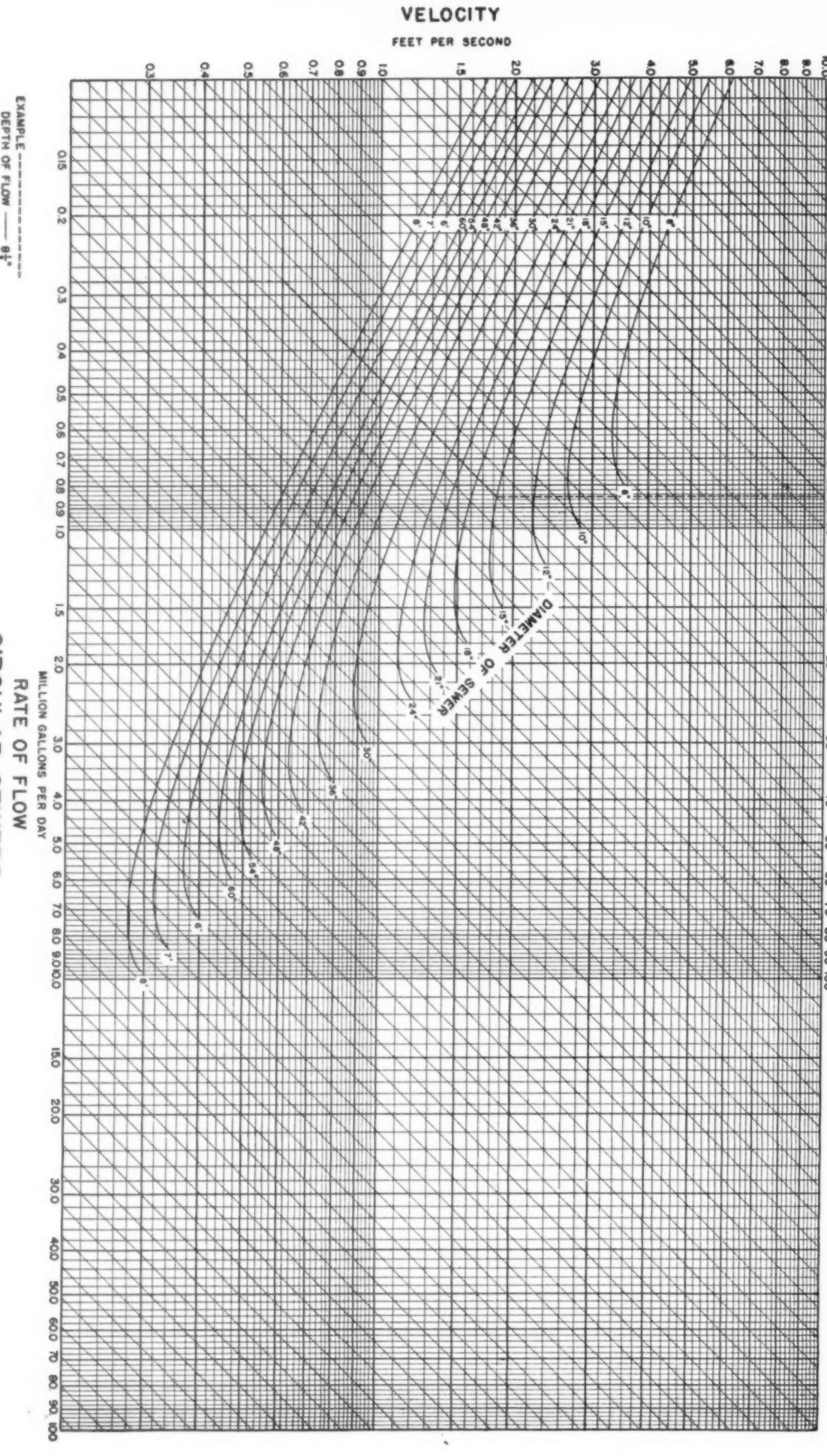
(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

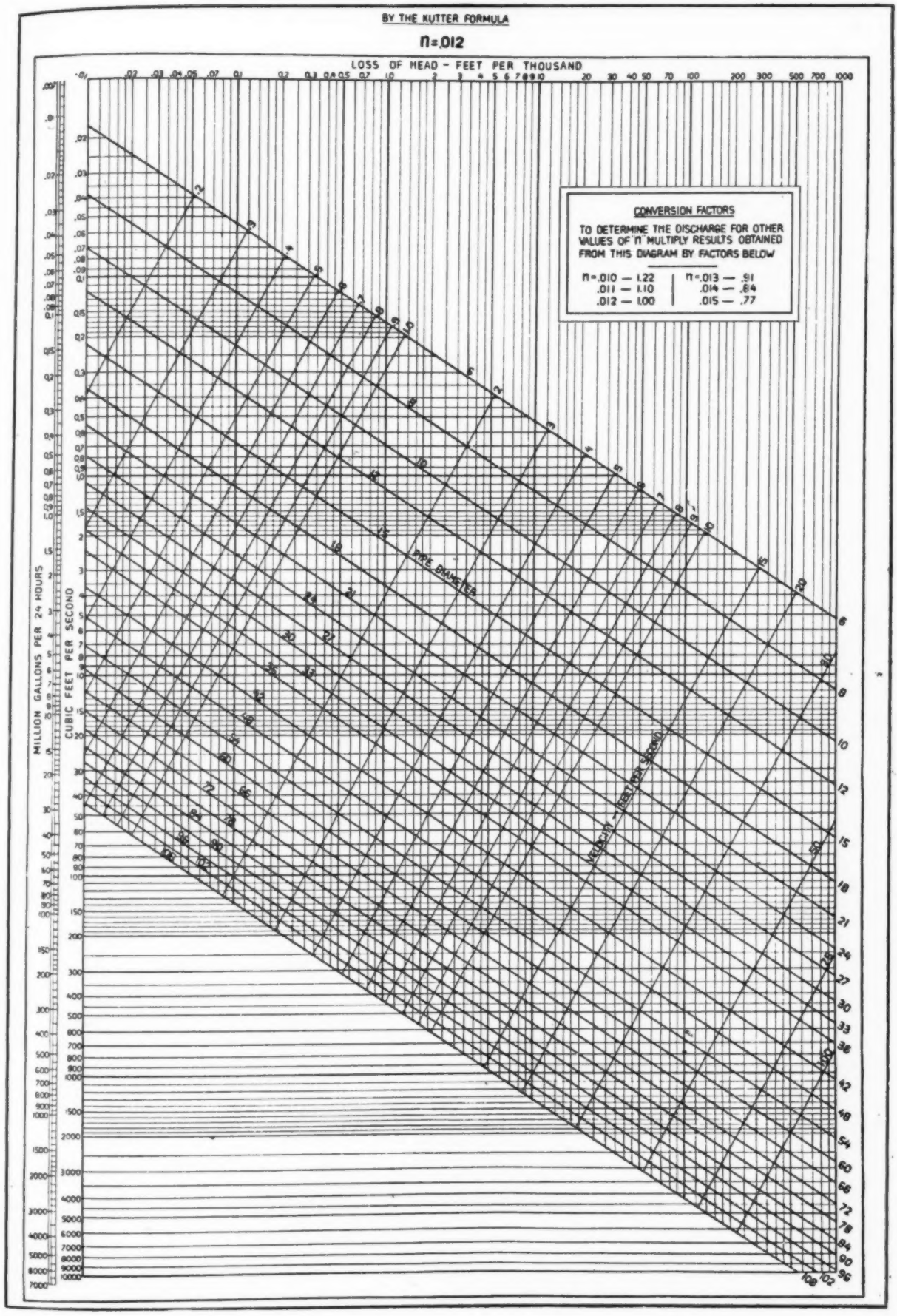
No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....



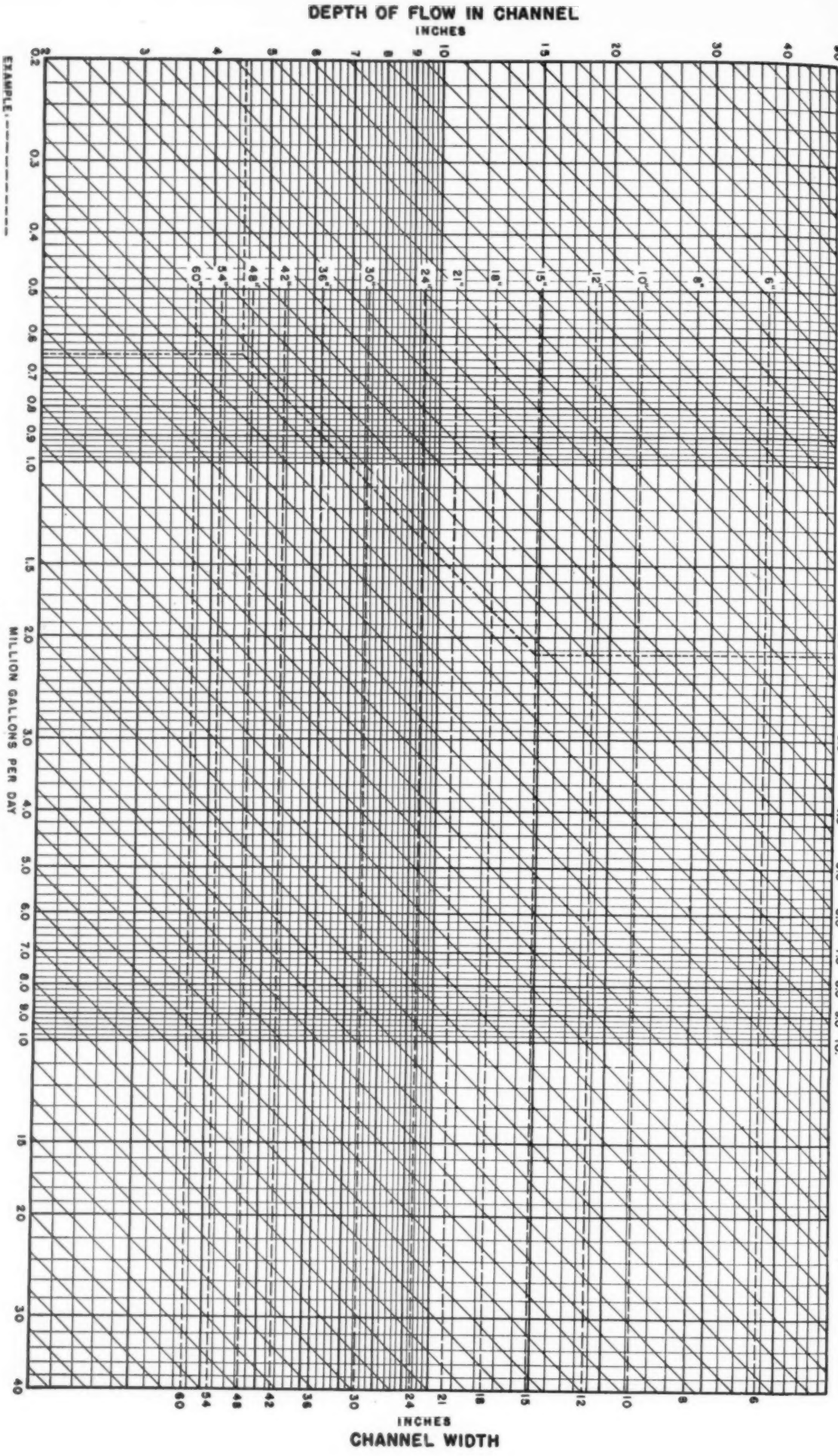
RATE OF FLOW
CIRCULAR SEWERS

This very useful graph for use in design or in determining velocities or rates of flow in existing pipe lines and sewers is reproduced through courtesy of Chicago Pump Co.

FLOWS THROUGH CONCRETE PIPE

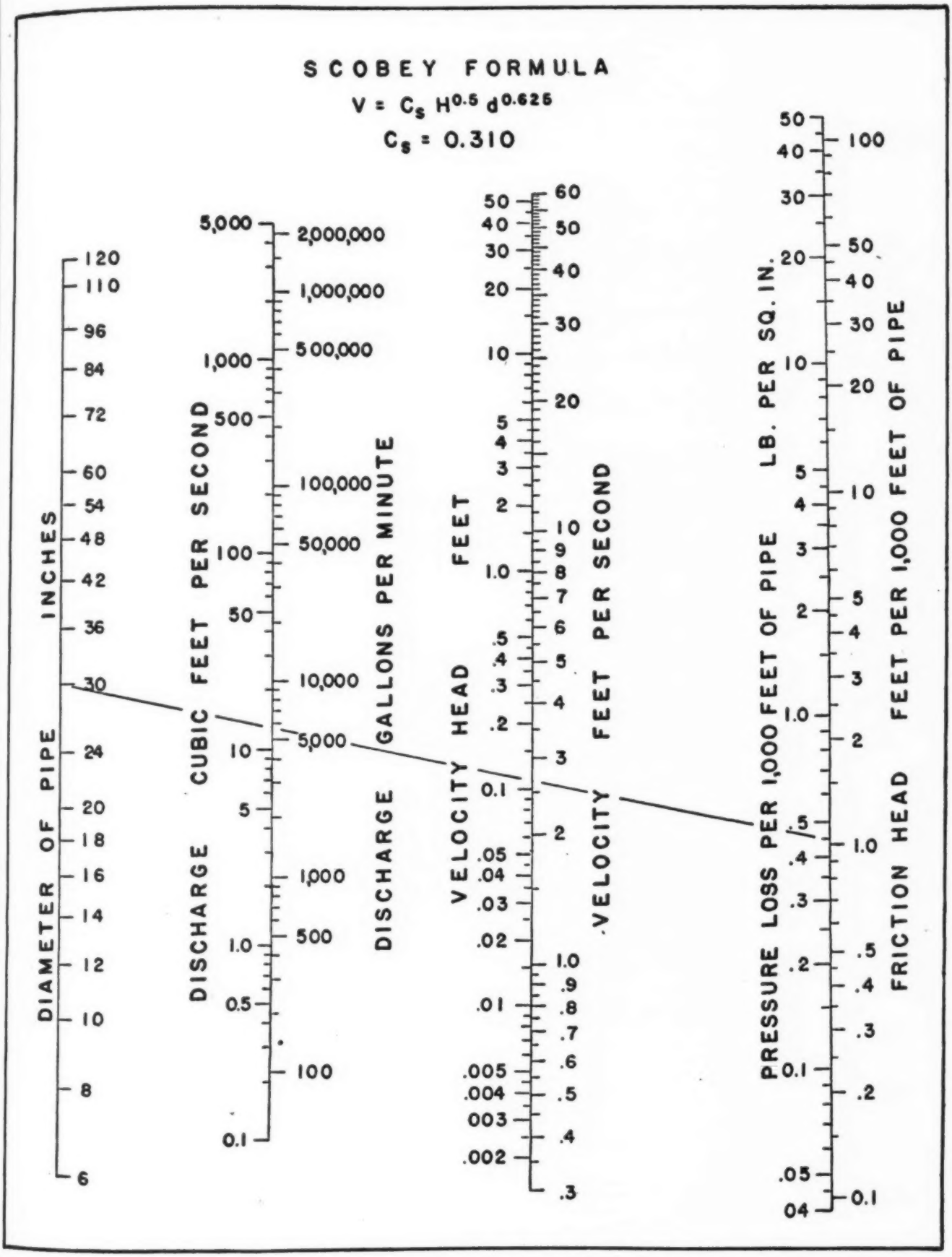

BY THE KUTTER FORMULA
n=.012
LOSS OF HEAD - FEET PER THOUSAND
MILLION GALLONS PER 24 HOURS
CUBIC FEET PER SECOND
PIPE DIAMETER
VELOCITY - FEET PER SECOND
CONVERSION FACTORS
TO DETERMINE THE DISCHARGE FOR OTHER VALUES OF n MULTIPLY RESULTS OBTAINED FROM THIS DIAGRAM BY FACTORS BELOW
n=.010 — 1.22
.011 — 1.10
.012 — 1.00
n=.013 — .91
.014 — .84
.015 — .77

A graph developed by N. D. Whitman, late Consulting Engineer of Los Angeles, appearing in "Concrete Pipe Lines," published by the American Concrete Pipe Association in 1942.



This very useful graph for use in design or in determining rates of flow or velocities in existing rectangular channels is reproduced through courtesy of Chicago Pump Co.

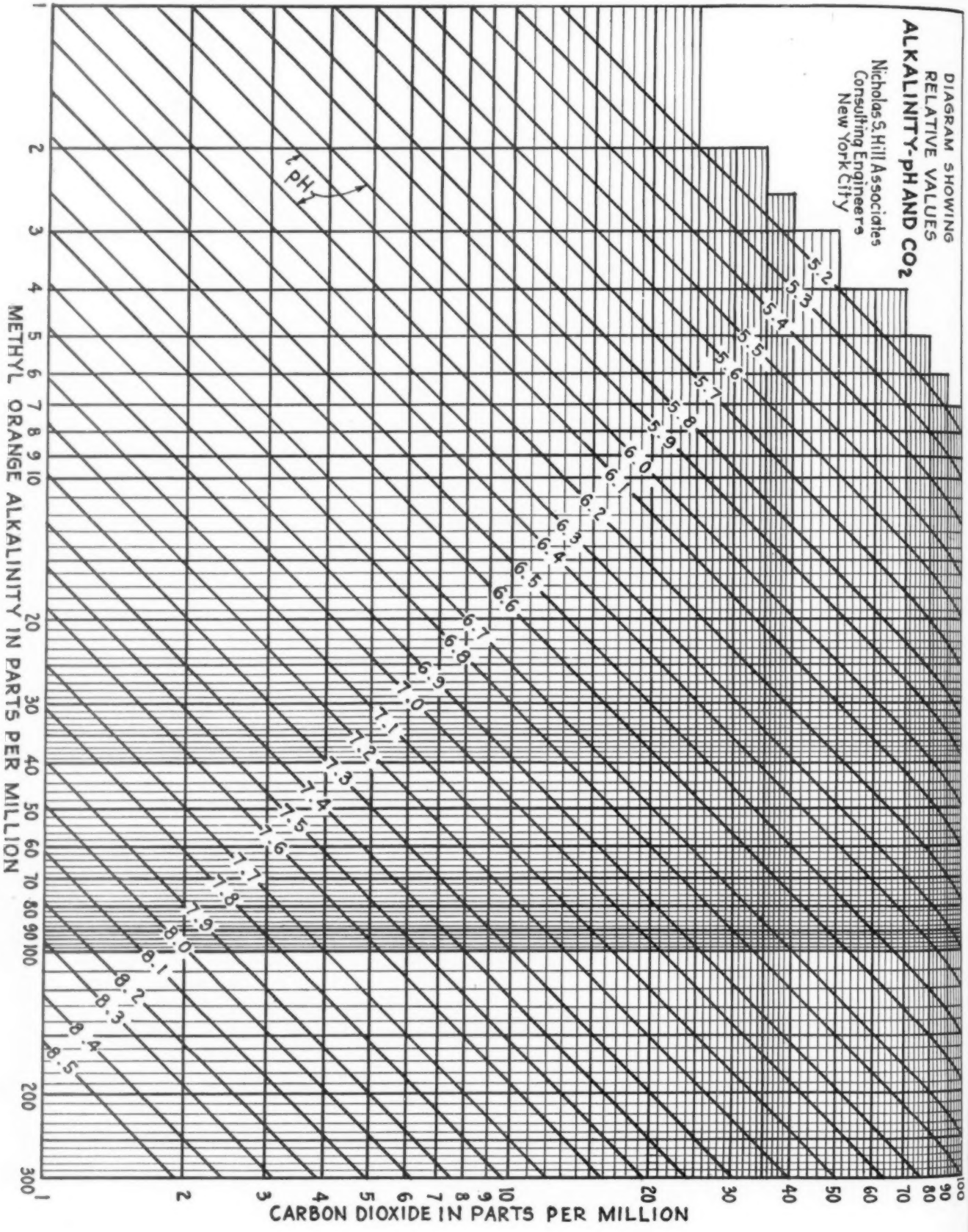
FLOW OF WATER IN CONCRETE PIPE


SCOBEY FORMULA
V = C_s $H^{0.5}$ $d^{0.625}$
C_s = 0.310
DIAMETER OF PIPE INCHES
DISCHARGE CUBIC FEET PER SECOND
DISCHARGE GALLONS PER MINUTE
VELOCITY HEAD FEET
VELOCITY FEET PER SECOND
PRESSURE LOSS PER 1,000 FEET OF PIPE LB. PER SQ. IN.
FRICTION HEAD FEET PER 1,000 FEET OF PIPE

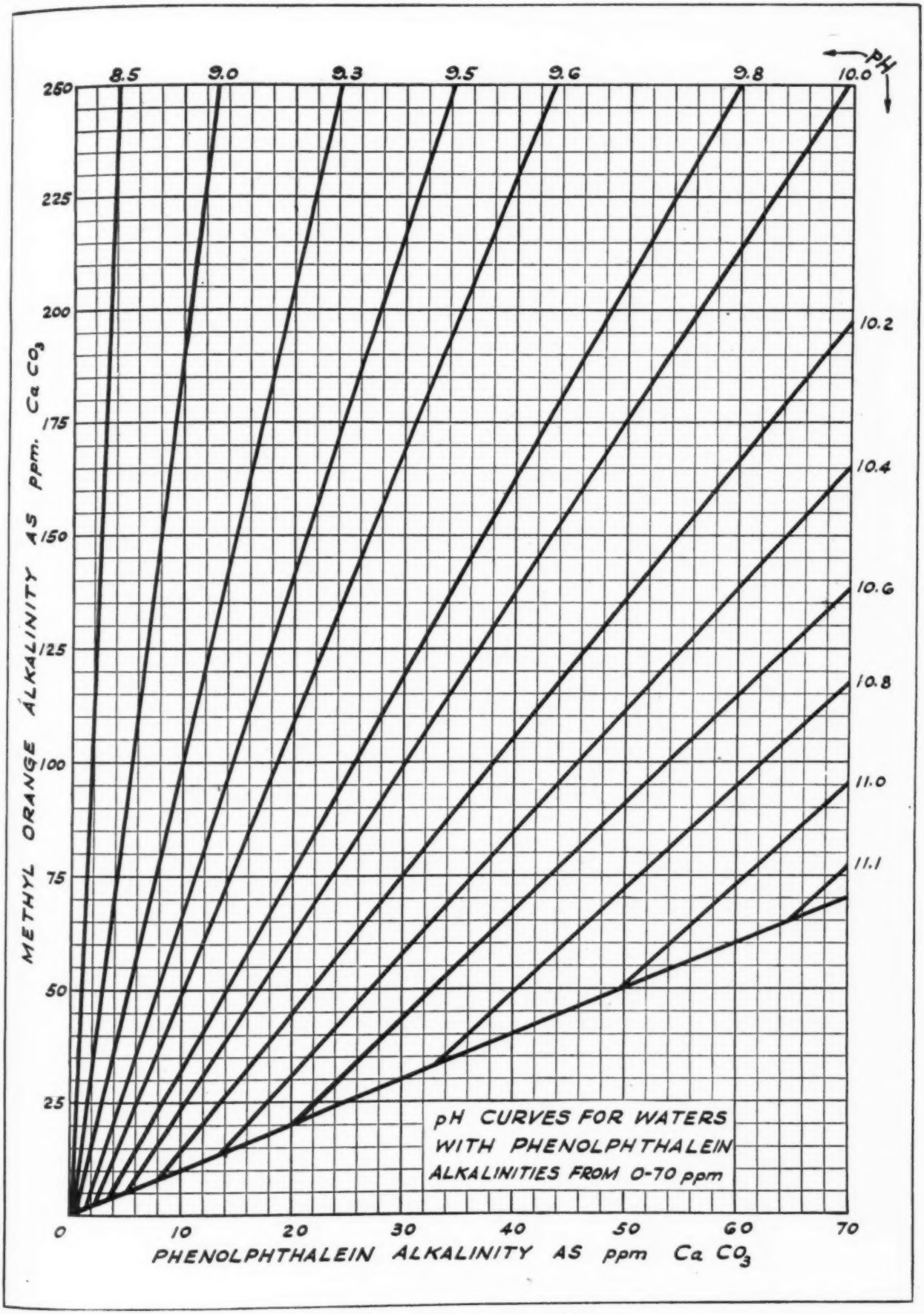
Courtesy of J R. Griffith, U. S. Navy, and Western Construction News.

pH CONVERSION CHART

NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with a kalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. Courtesy Nicholas S. Hill Associates, New York City.*



EFFECT OF CARBONATE AND BICARBONATE ALKALINITY ON pH



From Permutit Company's Data Book

VELOCITY IN PIPES

Rate of Flow in Gals. per Min.	NOMINAL DIAMETER OF PIPE														Rate of Flow in Gals. per Min.
	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	
	(Velocity in Feet Per Second)														
1	5.60	3.08	1.67	1.05											1
2		6.16	3.35	2.10	1.20										2
3			5.02	3.16	1.80	1.12									3
4			6.70	4.21	2.41	1.49	0.86	0.63							4
5			8.37	5.26	3.01	1.86	1.07	0.79							5
10				10.52	6.02	3.72	2.14	1.57	1.02	0.65	0.45				10
15					9.02	5.60	3.21	2.36	1.53	0.98	0.68				15
20					12.03	7.44	4.29	3.15	2.04	1.31	0.91				20
25						9.30	5.36	3.94	2.55	1.63	1.13				25
30						11.15	6.43	4.72	3.06	1.96	1.36				30
35						13.02	7.51	5.51	3.57	2.29	1.58				35
40						14.88	8.58	6.30	4.08	2.61	1.82	1.02			40
45							9.65	7.08	4.60	2.94	2.04	1.15			45
50							10.72	7.87	5.11	3.27	2.27	1.28			50
70							15.01	11.02	7.15	4.58	3.18	1.79	1.14		70
75								11.80	7.66	4.90	3.40	1.92	1.22		75
100								15.74	10.21	6.54	4.54	2.55	1.63	1.10	100
120								18.89	12.25	7.84	5.45	3.06	1.96	1.36	120
125									12.75	8.16	5.66	3.19	2.04	1.42	125
150									15.32	9.80	6.80	3.84	2.45	1.70	150
175									17.85	11.40	7.94	4.46	2.86	1.98	175
200	8"								20.42	13.07	9.08	5.11	3.27	2.27	200
225										14.70	10.20	5.75	3.67	2.55	225
250	1.60									16.30	11.32	6.38	4.08	2.84	250
270	1.73										12.25	6.90	4.41	3.06	270
275	1.76										12.50	7.03	4.49	3.12	275
300	1.92										13.62	7.66	4.90	3.40	300
350	2.24	10"										8.94	5.72	3.98	350
400	2.56											10.21	6.54	4.54	400
450	2.88	1.84										11.49	7.35	5.11	450
470	3.01	1.92	12"									12.00	7.68	5.34	470
475	3.04	1.94										12.10	7.75	5.40	475
500	3.20	2.04	1.42									12.77	8.17	5.68	500
550	3.52	2.25	1.56										8.99	6.24	550
600	3.84	2.45	1.70	14"									9.80	6.81	600
650	4.16	2.65	1.85	1.30									10.62	7.38	650
700	4.48	2.86	1.99	1.40									11.44	7.94	700
750	4.80	3.06	2.13	1.50									12.26	8.50	750
800	5.12	3.27	2.27	1.60										9.08	800
850	5.45	3.47	2.41	1.70	15"									9.65	850
900	5.76	3.67	2.56	1.80	1.67									10.20	900
950	6.08	3.88	2.70	1.90	1.76									10.77	950
1000	6.40	4.08	2.84	2.00	1.85									11.34	1000
1050	6.72	4.29	2.98	2.10	1.93									11.90	1050
1100	7.04	4.49	3.13	2.20										12.48	1100
1150	7.36	4.70	3.27	2.30	2.02	16"								13.05	1150
1200	7.68	4.90	3.41	2.40	2.11									13.61	1200
1250	8.00	5.41	3.55	2.50	2.20	1.99								14.20	1250
1500	9.60	6.12	4.26	3.05	2.64	2.09									1500
2000	12.80	8.10	5.68	4.00	3.52	3.09	20"								2000
2500		10.20	7.10	5.01	4.40	3.98	3.07	24"							2500
3000		12.24	8.52	6.01	5.28	4.78	3.53	2.43	30"						3000
3500		14.50	9.95	7.02	6.16	5.58	4.10	2.83	1.81						3500
4000			11.36	8.02	7.04	6.33	4.30	2.97	1.90						4000
4200			11.92	8.42	7.40	6.70									4200
4500			12.78	9.02	7.92	7.17	4.61	3.19	2.04	36"					4500
5000			14.20	10.02	8.80	7.96	5.12	3.54	2.26						5000
5500				11.01	9.69	8.77	5.63	3.90	2.49	1.57					5500
6000				12.00	10.56	9.56	6.14	4.25	2.72	2.05					6000
6500				13.00	11.44	10.36	6.66	4.60	2.94						6500
7000				14.02	12.32	11.16	7.16	4.97	3.17	2.21					7000
7200					13.20	11.50	7.38	5.16	3.26	2.27					7200
7500					14.00	11.96	7.68	5.32	3.40	2.37					7500
8000							8.20	5.66	3.62	2.52					8000
8500							8.70	6.02	3.85	2.68					8500
9000							9.21	6.38	4.08	2.84	42"				9000
9500							9.72	6.72	4.31	3.00					9500
10000							10.24	7.08	4.58	3.15	2.31				10000
10500								7.44	4.76	3.30	2.43				10500
11000								7.79	4.99	3.46	2.55				11000
11500								8.15	5.22	3.62	2.66				11500
12000								8.50	5.44	3.78	2.78				12000
12500								8.85	5.67	3.93	2.89				12500
13000								9.20	5.90	4.00	3.01				13000
13500								9.56	6.12	4.25	3.13				13500

This table is taken from "Hydraulic Data," published by Gould's Pumps, Inc.

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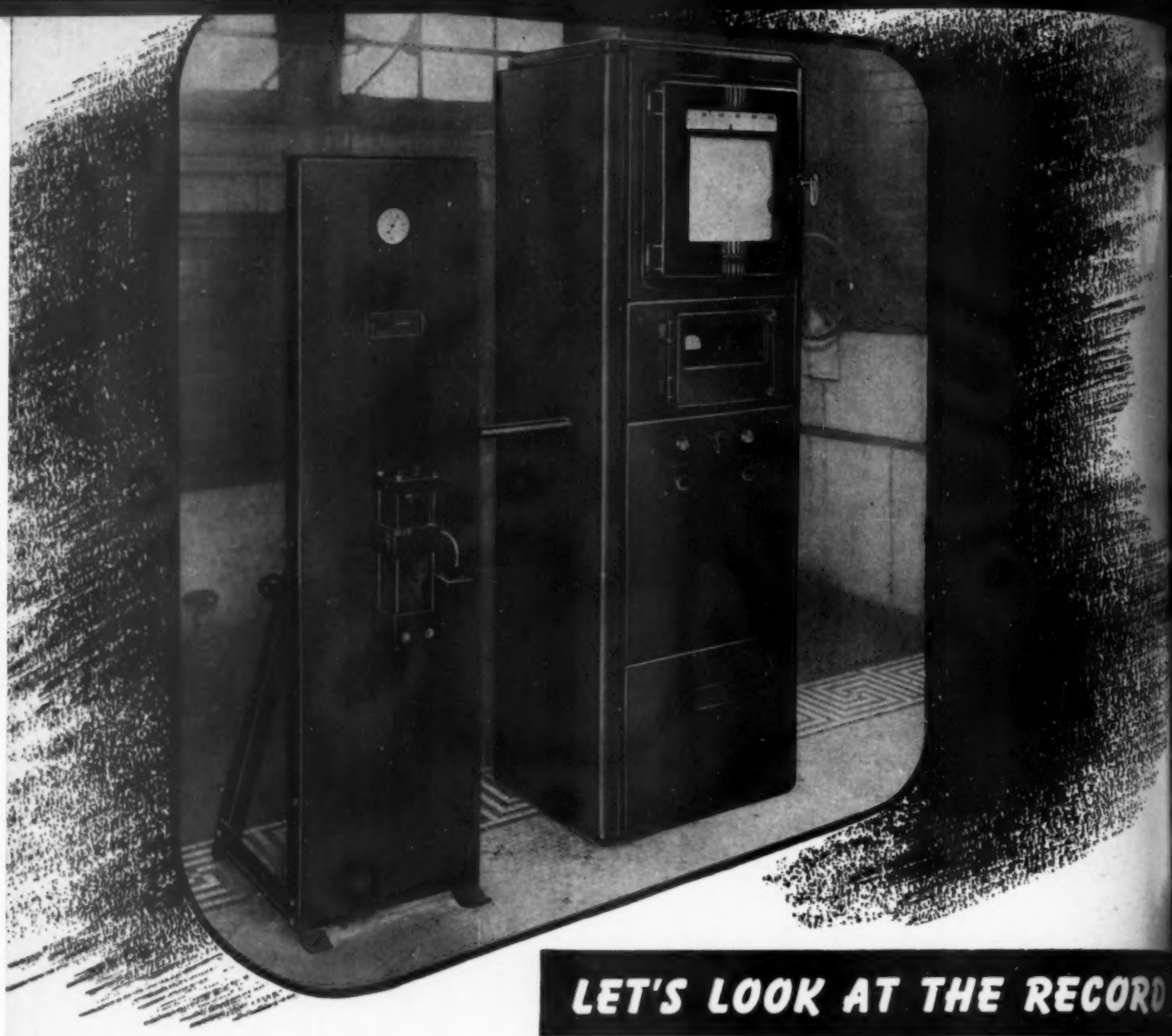

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